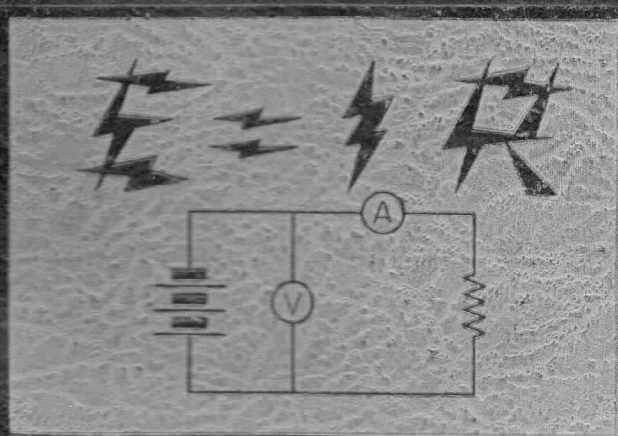


ALLIED'S ELECTRONICS DATA HANDBOOK

DONALD G. RILL



ALLIED RADIO CORPORATION

CHICAGO

546 $\overline{) 35000}$
3276
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FOREWORD

$200 = \frac{546}{350}$
x

Allied Radio Corporation has long recognized the need for a comprehensive and condensed handbook of formulas and data most commonly used in the field of radio and electronics. It was felt also that such a book should serve entirely as a convenient source of information and reference and that all attempts to teach or explain the basic principles involved should be left to classroom instruction and to the many already existing publications written for this distinct purpose.

The *Electronics Data Handbook*, therefore, consists of formulas, tables, charts and data. Every effort has been made to present this information clearly and to arrange it in a convenient manner for instant reference. All material was carefully selected and prepared by *Allied's* technical staff to serve the requirements of many specific groups in the radio and electronics field. It is hoped that our objectives have been successfully attained and that this *Handbook* will serve as: (1) A valuable adjunct to classroom study and laboratory work for the student and instructor; (2) A dependable source of information for the beginner, experimenter and set builder; (3) A reliable guide for the service engineer and maintenance man in his everyday work; (4) A time-saving and practical reference for the radio amateur, technician and engineer, both in the laboratory and in the field of operations.

The publishers are indebted to the McGraw-Hill Book Company, Inc., for their permission to use material selected from "*Mathematics for Electricians and Radiomen*" by Nelson M. Cooke. *Allied* also takes this opportunity to thank those manufacturers who so generously permitted our use of current data prepared by their engineering personnel. Special recognition and our sincere appreciation are extended to Commander Cooke for his helpful suggestions and generous contribution of his time and specialized knowledge in editing the material contained in this book.

ALLIED RADIO CORPORATION

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Mathematical Symbols

| | |
|---------------------|-------------------------------------|
| \times or \cdot | Multiplied by |
| \div or $:$ | Divided by |
| $+$ | Positive. Plus. Add |
| $-$ | Negative. Minus. Subtract |
| \pm | Positive or negative. Plus or minus |
| $+$ | Negative or positive. Minus or plus |
| $=$ or $::$ | Equals |
| \equiv | Identity |
| \approx | Is approximately equal to |
| \neq | Does not equal |
| $>$ | Is greater than |
| \gg | Is much greater than |
| $<$ | Is less than |
| \ll | Is much less than |
| \geq | Greater than or equal to |
| \leq | Less than or equal to |
| \therefore | Therefore |
| \angle | Angle |
| Δ | Increment or Decrement |
| \perp | Perpendicular to |
| \parallel | Parallel to |
| $ n $ | Absolute value of n |

Mathematical Constants

| | |
|--------------------------------|-------------------------------|
| $\pi = 3.14$ | $\sqrt{\pi} = 1.77$ |
| $2\pi = 6.28$ | $\sqrt{\frac{\pi}{2}} = 1.25$ |
| $(2\pi)^2 = 39.5$ | $\sqrt{2} = 1.41$ |
| $4\pi = 12.6$ | $\sqrt{3} = 1.73$ |
| $\pi^2 = 9.87$ | $\frac{1}{\sqrt{2}} = 0.707$ |
| $\frac{\pi}{2} = 1.57$ | $\frac{1}{\sqrt{3}} = 0.577$ |
| $\frac{1}{\pi} = 0.318$ | $\log \pi = 0.497$ |
| $\frac{1}{2\pi} = 0.159$ | $\log \frac{\pi}{2} = 0.196$ |
| $\frac{1}{\pi^2} = 0.101$ | $\log \pi^2 = 0.994$ |
| $\frac{1}{\sqrt{\pi}} = 0.564$ | $\log \sqrt{\pi} = 0.248$ |

Decimal Inches

| | | |
|-----------------|------------------------|---------------|
| Inches \times | 2.540 | = Centimeters |
| Inches \times | 1.578×10^{-5} | = Miles |
| Inches \times | 10^3 | = Mils |

| Inches | | Decimal Equivalent | Millimeter Equivalent |
|--------|-------|--------------------|-----------------------|
| 1/64 | 1/32 | .0156 .0313 | 0.397 0.794 |
| 3/64 | | .0469 .0625 | 1.191 1.588 |
| 5/64 | 3/32 | .0781 .0938 | 1.985 2.381 |
| 7/64 | | .1094 .1250 | 2.778 3.175 |
| 9/64 | 5/32 | .1406 .1563 | 3.572 3.969 |
| 11/64 | | .1719 .1875 | 4.366 4.762 |
| 13/64 | 7/32 | .2031 .2188 | 5.159 5.556 |
| 15/64 | | .2344 .2500 | 5.953 6.350 |
| 17/64 | 9/32 | .2656 .2813 | 6.747 7.144 |
| 19/64 | | .2969 .3125 | 7.541 7.937 |
| 21/64 | 11/32 | .3281 .3438 | 8.334 8.731 |
| 23/64 | | .3594 .3750 | 9.128 9.525 |
| 25/64 | 13/32 | .3906 .4063 | 9.922 10.319 |
| 27/64 | | .4219 .4375 | 10.716 11.112 |
| 29/64 | 15/32 | .4531 .4688 | 11.509 11.906 |
| 31/64 | | .4844 .5000 | 12.303 12.700 |
| 33/64 | 17/32 | .5156 .5313 | 13.097 13.494 |
| 35/64 | | .5469 .5625 | 13.891 14.287 |
| 37/64 | 19/32 | .5781 .5938 | 14.684 15.081 |
| 39/64 | | .6094 .6250 | 15.478 15.875 |
| 41/64 | 21/32 | .6406 .6563 | 16.272 16.669 |
| 43/64 | | .6719 .6875 | 17.067 17.463 |
| 45/64 | 23/32 | .7031 .7188 | 17.860 18.258 |
| 47/64 | | .7344 .7500 | 18.635 19.049 |
| 49/64 | 25/32 | .7656 .7813 | 19.446 19.842 |
| 51/64 | | .7969 .8125 | 20.239 20.636 |
| 53/64 | 27/32 | .8281 .8438 | 21.033 21.430 |
| 55/64 | | .8594 .8750 | 21.827 22.224 |
| 57/64 | 29/32 | .8906 .9063 | 22.621 23.018 |
| 59/64 | | .9219 .9375 | 23.415 23.812 |
| 61/64 | 31/32 | .9531 .9688 | 24.209 24.606 |
| 63/64 | | .9844 1.0000 | 25.004 25.400 |

Algebra

Exponents and Radicals

$$a^x \times a^y = a^{(x+y)}, \quad \frac{a^x}{a^y} = a^{(x-y)}.$$

$$(ab)^x = a^x b^x, \quad \left(\frac{a}{b}\right)^x = \frac{a^x}{b^x}.$$

$$\sqrt[x]{\frac{a}{b}} = \frac{\sqrt[x]{a}}{\sqrt[x]{b}}, \quad a^{-x} = \frac{1}{a^x}.$$

$$(a^x)^y = a^{xy}, \quad \sqrt[x]{y/a} = y/\sqrt[x]{a}.$$

$$\sqrt[x]{ab} = \sqrt[x]{a} \sqrt[x]{b}, \quad \frac{a^x}{a^y} = \sqrt[x]{a^{x-y}}.$$

$$a^{\frac{1}{x}} = \sqrt[x]{a}, \quad a^0 = 1.$$

Solution of a Quadratic

Quadratic equations in the form

$$ax^2 + bx + c = 0$$

may be solved by the following:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

Transposition of Terms

$$\text{If } A = \frac{B}{C}, \text{ then } B = AC, \quad C = \frac{B}{A}.$$

$$\text{If } \frac{A}{B} = \frac{C}{D}, \text{ then } A = \frac{BC}{D},$$

$$B = \frac{AD}{C}, \quad C = \frac{AD}{B}, \quad D = \frac{BC}{A}.$$

$$\text{If } A = \frac{1}{D\sqrt{BC}}, \text{ then } A^2 = \frac{1}{D^2BC},$$

$$B = \frac{1}{D^2A^2C}, \quad C = \frac{1}{D^2A^2B}, \quad D = \frac{1}{A\sqrt{BC}}.$$

$$\text{If } A = \sqrt{B^2 + C^2}, \text{ then } A^2 = B^2 + C^2,$$

$$B = \sqrt{A^2 - C^2}, \quad C = \sqrt{A^2 - B^2}.$$

Decibels

The number of db by which two power outputs P_1 and P_2 (in watts) may differ, is expressed by

$$10 \log \frac{P_1}{P_2};$$

or in terms of volts,

$$20 \log \frac{E_1}{E_2};$$

or in current,

$$20 \log \frac{I_1}{I_2}.$$

While power ratios are independent of source and load impedance values, voltage and current ratios in these formulas hold true only when the source and load impedances Z_1 and Z_2 are equal. In circuits where these impedances differ, voltage and current ratios are expressed by,

$$db = 20 \log \frac{E_1 \sqrt{Z_2}}{E_2 \sqrt{Z_1}} \quad \text{or,} \quad 20 \log \frac{I_1 \sqrt{Z_1}}{I_2 \sqrt{Z_2}}$$

DB Expressed in Watts & Volts

| DB * | Above Zero Level | | Below Zero Level | |
|------|------------------|---------|------------------------|----------|
| | Watts | Volts | Watts | Volts |
| 0 | 0.00600 | 1.73 | 6.00×10^{-3} | 1.73 |
| 1 | 0.00755 | 1.94 | 4.77×10^{-3} | 1.54 |
| 2 | 0.00951 | 2.18 | 3.78×10^{-3} | 1.38 |
| 3 | 0.0120 | 2.45 | 3.01×10^{-3} | 1.23 |
| 4 | 0.0151 | 2.74 | 2.39×10^{-3} | 1.09 |
| 5 | 0.0190 | 3.08 | 1.90×10^{-3} | 0.974 |
| 6 | 0.0239 | 3.46 | 1.51×10^{-3} | 0.868 |
| 7 | 0.0301 | 3.88 | 1.20×10^{-3} | 0.774 |
| 8 | 0.0378 | 4.35 | 9.51×10^{-4} | 0.690 |
| 9 | 0.0477 | 4.88 | 7.55×10^{-4} | 0.614 |
| 10 | 0.0600 | 5.48 | 6.00×10^{-4} | 0.548 |
| 11 | 0.0755 | 6.14 | 4.77×10^{-4} | 0.488 |
| 12 | 0.0951 | 6.90 | 3.78×10^{-4} | 0.435 |
| 13 | 0.120 | 7.74 | 3.01×10^{-4} | 0.388 |
| 14 | 0.151 | 8.68 | 2.39×10^{-4} | 0.346 |
| 15 | 0.190 | 9.74 | 1.90×10^{-4} | 0.308 |
| 16 | 0.239 | 10.93 | 1.51×10^{-4} | 0.275 |
| 17 | 0.301 | 12.26 | 1.20×10^{-4} | 0.245 |
| 18 | 0.378 | 13.76 | 9.51×10^{-5} | 0.218 |
| 19 | 0.477 | 15.44 | 7.55×10^{-5} | 0.194 |
| 20 | 0.600 | 17.32 | 6.00×10^{-5} | 0.173 |
| 25 | 1.90 | 30.8 | 1.90×10^{-5} | 0.0974 |
| 30 | 6.00 | 54.8 | 6.00×10^{-6} | 0.0548 |
| 35 | 19.0 | 97.4 | 1.90×10^{-6} | 0.0308 |
| 40 | 60.0 | 173. | 6.00×10^{-7} | 0.0173 |
| 45 | 190. | 308. | 1.90×10^{-7} | 0.00974 |
| 50 | 600. | 548. | 6.00×10^{-8} | 0.00548 |
| 60 | 6,000. | 1,730. | 6.00×10^{-9} | 0.00173 |
| 70 | 60,000. | 5,480. | 6.00×10^{-10} | 0.000548 |
| 80 | 600,000. | 17,300. | 6.00×10^{-11} | 0.000173 |

*Zero db = 6 milliwatts into a 500 ohm load. Power ratios hold for any impedance, but voltages must be referred to an impedance load of 500 ohms.

Decibel—Voltage, Current and Power Ratio Table

| — | | DB | + | | — | | DB | + | |
|-----------------------------------|----------------|-----|-----------------------------------|----------------|-----------------------------------|-------------------|-------|-----------------------------------|------------------|
| Voltage or Current Ratio | Power Ratio | | Voltage or Current Ratio | Power Ratio | Voltage or Current Ratio | Power Ratio | | Voltage or Current Ratio | Power Ratio |
| 1.0000 | 1.0000 | 0 | 1.000 | 1.000 | .4898 | .2399 | 6.2 | 2.042 | 4.169 |
| .9886 | .9772 | .1 | 1.012 | 1.023 | .4842 | .2344 | 6.3 | 2.065 | 4.266 |
| .9772 | .9550 | .2 | 1.023 | 1.047 | .4786 | .2291 | 6.4 | 2.089 | 4.365 |
| .9661 | .9333 | .3 | 1.035 | 1.072 | .4732 | .2239 | 6.5 | 2.113 | 4.467 |
| .9550 | .9120 | .4 | 1.047 | 1.096 | .4677 | .2188 | 6.6 | 2.138 | 4.571 |
| .9441 | .8913 | .5 | 1.059 | 1.122 | .4624 | .2138 | 6.7 | 2.163 | 4.677 |
| .9333 | .8710 | .6 | 1.072 | 1.148 | .4571 | .2089 | 6.8 | 2.188 | 4.786 |
| .9226 | .8511 | .7 | 1.084 | 1.175 | .4519 | .2042 | 6.9 | 2.213 | 4.898 |
| .9120 | .8318 | .8 | 1.096 | 1.202 | .4467 | .1995 | 7.0 | 2.239 | 5.012 |
| .9016 | .8128 | .9 | 1.109 | 1.230 | .4416 | .1950 | 7.1 | 2.265 | 5.129 |
| .8913 | .7943 | 1.0 | 1.122 | 1.259 | .4365 | .1905 | 7.2 | 2.291 | 5.248 |
| .8810 | .7762 | 1.1 | 1.135 | 1.288 | .4315 | .1862 | 7.3 | 2.317 | 5.370 |
| .8710 | .7586 | 1.2 | 1.148 | 1.318 | .4266 | .1820 | 7.4 | 2.344 | 5.495 |
| .8610 | .7413 | 1.3 | 1.161 | 1.349 | .4217 | .1778 | 7.5 | 2.371 | 5.623 |
| .8511 | .7244 | 1.4 | 1.175 | 1.380 | .4169 | .1738 | 7.6 | 2.399 | 5.754 |
| .8414 | .7079 | 1.5 | 1.189 | 1.413 | .4121 | .1698 | 7.7 | 2.427 | 5.888 |
| .8318 | .6918 | 1.6 | 1.202 | 1.445 | .4074 | .1660 | 7.8 | 2.455 | 6.026 |
| .8222 | .6761 | 1.7 | 1.216 | 1.479 | .4027 | .1622 | 7.9 | 2.483 | 6.166 |
| .8128 | .6607 | 1.8 | 1.230 | 1.514 | .3981 | .1585 | 8.0 | 2.512 | 6.310 |
| .8035 | .6457 | 1.9 | 1.245 | 1.549 | .3936 | .1549 | 8.1 | 2.541 | 6.457 |
| .7943 | .6310 | 2.0 | 1.259 | 1.585 | .3890 | .1514 | 8.2 | 2.570 | 6.607 |
| .7852 | .6166 | 2.1 | 1.274 | 1.622 | .3846 | .1479 | 8.3 | 2.600 | 6.761 |
| .7762 | .6026 | 2.2 | 1.288 | 1.660 | .3802 | .1445 | 8.4 | 2.630 | 6.918 |
| .7674 | .5888 | 2.3 | 1.303 | 1.698 | .3758 | .1413 | 8.5 | 2.661 | 7.079 |
| .7586 | .5754 | 2.4 | 1.318 | 1.738 | .3715 | .1380 | 8.6 | 2.692 | 7.244 |
| .7499 | .5623 | 2.5 | 1.334 | 1.778 | .3673 | .1349 | 8.7 | 2.723 | 7.413 |
| .7413 | .5495 | 2.6 | 1.349 | 1.820 | .3631 | .1318 | 8.8 | 2.754 | 7.586 |
| .7328 | .5370 | 2.7 | 1.365 | 1.862 | .3589 | .1288 | 8.9 | 2.786 | 7.762 |
| .7244 | .5248 | 2.8 | 1.380 | 1.905 | .3548 | .1259 | 9.0 | 2.818 | 7.943 |
| .7161 | .5129 | 2.9 | 1.396 | 1.950 | .3508 | .1230 | 9.1 | 2.851 | 8.128 |
| .7079 | .5012 | 3.0 | 1.413 | 1.995 | .3467 | .1202 | 9.2 | 2.884 | 8.318 |
| .6998 | .4898 | 3.1 | 1.429 | 2.042 | .3428 | .1175 | 9.3 | 2.917 | 8.511 |
| .6918 | .4786 | 3.2 | 1.445 | 2.089 | .3388 | .1148 | 9.4 | 2.951 | 8.710 |
| .6839 | .4677 | 3.3 | 1.462 | 2.138 | .3350 | .1122 | 9.5 | 2.985 | 8.913 |
| .6761 | .4571 | 3.4 | 1.479 | 2.188 | .3311 | .1096 | 9.6 | 3.020 | 9.120 |
| .6683 | .4467 | 3.5 | 1.496 | 2.239 | .3273 | .1072 | 9.7 | 3.055 | 9.333 |
| .6607 | .4365 | 3.6 | 1.514 | 2.291 | .3236 | .1047 | 9.8 | 3.090 | 9.550 |
| .6531 | .4266 | 3.7 | 1.531 | 2.344 | .3199 | .1023 | 9.9 | 3.126 | 9.772 |
| .6457 | .4169 | 3.8 | 1.549 | 2.399 | .3162 | .1000 | 10.0 | 3.162 | 10.000 |
| .6383 | .4074 | 3.9 | 1.567 | 2.455 | .2985 | .08913 | 10.5 | 3.350 | 11.22 |
| .6310 | .3981 | 4.0 | 1.585 | 2.512 | .2818 | .07943 | 11.0 | 3.548 | 12.59 |
| .6237 | .3890 | 4.1 | 1.603 | 2.570 | .2661 | .07079 | 11.5 | 3.758 | 14.13 |
| .6166 | .3802 | 4.2 | 1.622 | 2.630 | .2512 | .06310 | 12.0 | 3.981 | 15.85 |
| .6095 | .3715 | 4.3 | 1.641 | 2.692 | .2371 | .05623 | 12.5 | 4.217 | 17.78 |
| .6026 | .3631 | 4.4 | 1.660 | 2.754 | .2239 | .05012 | 13.0 | 4.467 | 19.95 |
| .5957 | .3548 | 4.5 | 1.679 | 2.818 | .2113 | .04467 | 13.5 | 4.732 | 22.39 |
| .5888 | .3467 | 4.6 | 1.698 | 2.884 | .1995 | .03981 | 14.0 | 5.012 | 25.12 |
| .5821 | .3388 | 4.7 | 1.718 | 2.951 | .1884 | .03548 | 14.5 | 5.309 | 28.18 |
| .5754 | .3311 | 4.8 | 1.738 | 3.020 | .1778 | .03162 | 15.0 | 5.623 | 31.62 |
| .5689 | .3236 | 4.9 | 1.758 | 3.090 | .1585 | .02512 | 16.0 | 6.310 | 39.81 |
| .5623 | .3162 | 5.0 | 1.778 | 3.162 | .1413 | .01995 | 17.0 | 7.079 | 50.12 |
| .5559 | .3090 | 5.1 | 1.799 | 3.236 | .1259 | .01585 | 18.0 | 7.943 | 63.10 |
| .5495 | .3020 | 5.2 | 1.820 | 3.311 | .1122 | .01259 | 19.0 | 8.913 | 79.43 |
| .5433 | .2951 | 5.3 | 1.841 | 3.388 | .1000 | .01000 | 20.0 | 10.000 | 100.00 |
| .5370 | .2884 | 5.4 | 1.862 | 3.467 | .03162 | .00100 | 30.0 | 31.620 | 1,000.00 |
| .5309 | .2818 | 5.5 | 1.884 | 3.548 | .01 | .00010 | 40.0 | 100.00 | 10,000.00 |
| .5248 | .2754 | 5.6 | 1.905 | 3.631 | .003162 | .00001 | 50.0 | 316.20 | 10 ⁵ |
| .5188 | .2692 | 5.7 | 1.928 | 3.715 | .001 | 10 ⁻⁶ | 60.0 | 1,000.00 | 10 ⁶ |
| .5129 | .2630 | 5.8 | 1.950 | 3.802 | .0003162 | 10 ⁻⁷ | 70.0 | 3,162.00 | 10 ⁷ |
| .5070 | .2570 | 5.9 | 1.972 | 3.890 | .0001 | 10 ⁻⁸ | 80.0 | 10,000.00 | 10 ⁸ |
| .5012 | .2512 | 6.0 | 1.995 | 3.931 | .00003162 | 10 ⁻⁹ | 90.0 | 31,620.00 | 10 ⁹ |
| .4955 | .2455 | 6.1 | 2.018 | 4.074 | 10 ⁻⁵ | 10 ⁻¹⁰ | 100.0 | 10 ⁵ | 10 ¹⁰ |

Table of Values for Attenuator Network Formulas

| db | A | B | C | D | E | db | A | B | C | D | E |
|-----|--------|---------|--------|---------|--------|-------|-----------|--------|-----------|--------|-----------|
| -1 | .98855 | .011447 | 86.360 | .005756 | 86.857 | 27.0 | .044668 | .95533 | .046757 | .91448 | .089515 |
| -2 | .97724 | .028273 | 42.931 | .011512 | 43.426 | 27.5 | .042170 | .95783 | .044026 | .91907 | .084490 |
| -3 | .97163 | .063772 | 34.247 | .014390 | 34.739 | 28.0 | .039811 | .96019 | .041461 | .92343 | .079748 |
| -4 | .96605 | .034046 | 28.456 | .017268 | 28.947 | 30.0 | .031623 | .96838 | .032655 | .93869 | .063309 |
| -5 | .95499 | .045008 | 21.219 | .023022 | 21.707 | 32.0 | .025119 | .97488 | .025766 | .95099 | .050269 |
| -6 | .94406 | .055939 | 16.876 | .028774 | 17.362 | 33.5 | .023714 | .97629 | .024290 | .95367 | .047454 |
| -7 | .93325 | .066745 | 13.982 | .034525 | 14.428 | 35.0 | .022387 | .97761 | .022900 | .95621 | .044797 |
| -8 | .92257 | .077429 | 11.915 | .040274 | 12.395 | 36.0 | .019953 | .98005 | .020359 | .96088 | .039921 |
| -9 | .91201 | .087989 | 10.365 | .046019 | 10.842 | 37.5 | .017783 | .98222 | .018105 | .96506 | .035577 |
| -10 | .90157 | .098429 | 9.1596 | .051762 | 9.6337 | 38.0 | .015849 | .98415 | .016104 | .96880 | .031706 |
| -11 | .89125 | .10875 | 8.1955 | .057501 | 8.6667 | 39.0 | .013335 | .98666 | .013515 | .97368 | .026675 |
| -12 | .88140 | .11860 | 7.3050 | .063133 | 7.7619 | 40.0 | .011220 | .98788 | .011348 | .97513 | .025183 |
| -13 | .87193 | .12797 | 6.5302 | .068633 | 6.9619 | 41.0 | .009000 | .98878 | .009101 | .97621 | .024443 |
| -14 | .86284 | .13694 | 5.8581 | .074022 | 6.3048 | 42.0 | .0079433 | .99000 | .008069 | .98020 | .020002 |
| -15 | .85406 | .14551 | 5.2727 | .079274 | 5.7619 | 42.5 | .0070433 | .99206 | .007556 | .98424 | .015888 |
| -16 | .84556 | .15368 | 4.7666 | .084422 | 5.2385 | 43.0 | .0063096 | .99250 | .0063496 | .98511 | .014999 |
| -17 | .83734 | .16147 | 4.3267 | .089589 | 4.8179 | 44.0 | .0056234 | .99369 | .0056552 | .98746 | .012620 |
| -18 | .82939 | .16888 | 3.9504 | .094717 | 4.4067 | 45.0 | .0050234 | .99438 | .0050528 | .98882 | .011247 |
| -19 | .82169 | .17593 | 3.6267 | .099804 | 4.0051 | 47.5 | .0042170 | .99578 | .0042348 | .99160 | .0084341 |
| -20 | .81424 | .18262 | 3.3466 | .104848 | 3.6267 | 48.0 | .0039811 | .99602 | .0039970 | .99207 | .0079623 |
| -21 | .80699 | .18904 | 3.1048 | .109728 | 3.3228 | 50.0 | .0031623 | .99684 | .0031723 | .99370 | .0063246 |
| -22 | .80000 | .19494 | 2.8948 | .114479 | 3.0228 | 51.0 | .0028184 | .99718 | .0028264 | .99438 | .0056368 |
| -23 | .79324 | .20047 | 2.7129 | .11908 | 2.7267 | 52.0 | .0025119 | .99749 | .0025182 | .99499 | .0050238 |
| -24 | .78671 | .20573 | 2.5566 | .12356 | 2.4966 | 54.0 | .0021953 | .99800 | .0021993 | .99502 | .0039905 |
| -25 | .78040 | .21073 | 2.4227 | .12793 | 2.2826 | 55.0 | .0017783 | .99822 | .0017815 | .99602 | .0035566 |
| -26 | .77431 | .21548 | 2.3084 | .13218 | 2.0966 | 56.0 | .0015849 | .99842 | .0015874 | .99645 | .0031698 |
| -27 | .76844 | .21999 | 2.2109 | .13634 | 1.8465 | 57.0 | .0014125 | .99859 | .0014145 | .99718 | .0028251 |
| -28 | .76279 | .22426 | 2.1267 | .14042 | 1.6485 | 58.0 | .0012519 | .99875 | .0012519 | .99749 | .0025024 |
| -29 | .75734 | .22828 | 2.0536 | .14442 | 1.4732 | 60.0 | .0010000 | .99900 | .0010010 | .99800 | .0020000 |
| -30 | .75209 | .23204 | 1.9898 | .14834 | 1.3186 | 64.0 | .00063096 | .99937 | .00063136 | .99874 | .0012619 |
| -31 | .74694 | .23556 | 1.9348 | .15218 | 1.1845 | 65.0 | .00056234 | .99944 | .00056265 | .99888 | .0011247 |
| -32 | .74189 | .23894 | 1.8879 | .15594 | 1.0667 | 66.0 | .00050119 | .99950 | .00050144 | .99900 | .0010024 |
| -33 | .73694 | .24218 | 1.8479 | .15962 | .9617 | 68.0 | .00039811 | .99960 | .00039827 | .99920 | .0007962 |
| -34 | .73209 | .24528 | 1.8148 | .16322 | .8723 | 70.0 | .00031623 | .99968 | .00031633 | .99937 | .0006325 |
| -35 | .72734 | .24824 | 1.7874 | .16674 | .7968 | 72.0 | .00025119 | .99975 | .00025125 | .99950 | .0005024 |
| -36 | .72269 | .25107 | 1.7648 | .17018 | .7266 | 75.0 | .00017783 | .99982 | .00017786 | .99964 | .0003557 |
| -37 | .71814 | .25377 | 1.7468 | .17346 | .6673 | 76.0 | .00015849 | .99984 | .00015851 | .99968 | .0003170 |
| -38 | .71369 | .25634 | 1.7309 | .17662 | .6150 | 78.0 | .00012589 | .99987 | .00012591 | .99975 | .0002518 |
| -39 | .70934 | .25878 | 1.7169 | .17968 | .5726 | 80.0 | .00010000 | .99990 | .00010000 | .99980 | .0002000 |
| -40 | .70509 | .26109 | 1.7048 | .18262 | .5321 | 84.0 | .00006310 | .99994 | .00006310 | .99987 | .0001262 |
| -41 | .70094 | .26326 | 1.6948 | .18548 | .4926 | 85.0 | .00005623 | .99994 | .00005624 | .99989 | .0001125 |
| -42 | .69689 | .26531 | 1.6867 | .18828 | .4548 | 90.0 | .00003162 | .99997 | .00003162 | .99994 | .00006325 |
| -43 | .69294 | .26724 | 1.6797 | .19108 | .4183 | 95.0 | .00001778 | .99998 | .00001778 | .99996 | .00003557 |
| -44 | .68909 | .26904 | 1.6734 | .19382 | .3832 | 96.0 | .00001585 | .99998 | .00001585 | .99997 | .00003170 |
| -45 | .68534 | .27073 | 1.6676 | .19651 | .3495 | 100.0 | .00001000 | .99999 | .00001000 | .99998 | .00002000 |

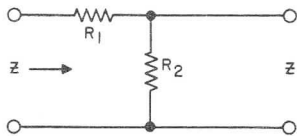
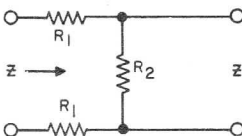
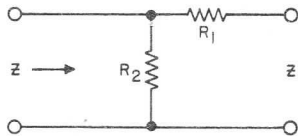
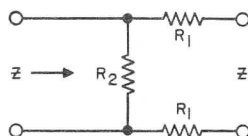
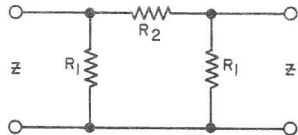
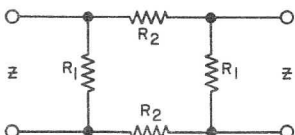
Attenuator Networks

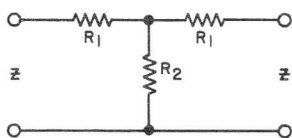
For Insertion Between Equal Impedances

For data covering networks between unequal impedances, see Minimum Loss Pads on page 10. See also Decibel—Voltage Current and Power Ratio Table on page 6.

See table on page 7 for values of A, B, C, D, E used in the following attenuator network formulas.

In the case of L and U networks where only the input or output can be matched, as required, the matched side is indicated by an arrow pointing toward the pad. On all other networks, both the input and output circuits are matched.

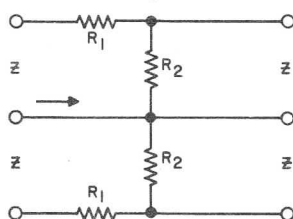
| | |
|---|---|
|  $R_1 = ZB$ $R_2 = ZC$ <p>L</p> |  $R_1 = \frac{ZB}{2}$ $R_2 = ZC$ <p>U</p> |
|  $R_1 = \frac{Z}{C}$ $R_2 = \frac{Z}{B}$ <p>L</p> |  $R_1 = \frac{Z}{2C}$ $R_2 = \frac{Z}{B}$ <p>U</p> |
|  $R_1 = \frac{Z}{D}$ $R_2 = \frac{Z}{E}$ <p>π</p> |  $R_1 = \frac{Z}{D}$ $R_2 = \frac{Z}{2E}$ <p>O</p> |



T

$$R_1 = ZD$$

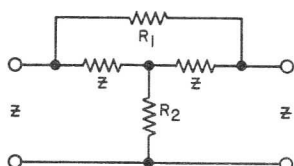
$$R_2 = ZE$$



Balanced U

$$R_1 = \frac{ZB}{2}$$

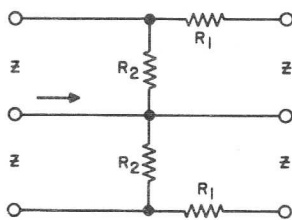
$$R_2 = \frac{ZC}{2}$$



Bridged T

$$R_1 = \frac{Z}{C}$$

$$R_2 = ZC$$



Balanced U

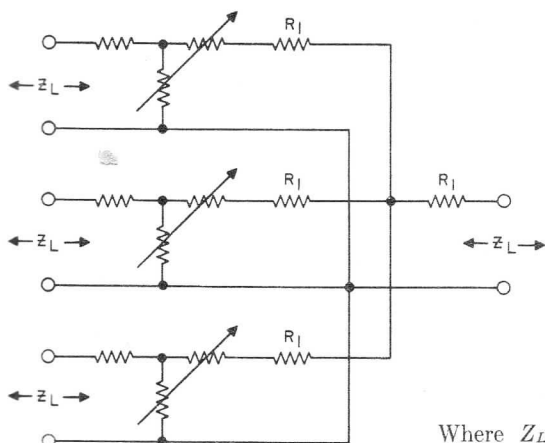
$$R_1 = \frac{Z}{2C}$$

$$R_2 = \frac{Z}{2B}$$

Constant Impedance Attenuators in Parallel

Table of R_1 Values in Ohms

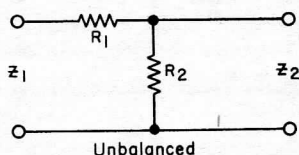
| Z | Number of Channels | | | | |
|-----------------|--------------------|-----|-----|------|------|
| | 2 | 3 | 4 | 5 | 6 |
| 30 | 10 | 15 | 18 | 20 | 21.5 |
| 50 | 16.6 | 25 | 30 | 33.3 | 35.7 |
| 150 | 50 | 75 | 90 | 100 | 107 |
| 200 | 66.6 | 100 | 120 | 133 | 143 |
| 250 | 83.3 | 125 | 150 | 166 | 179 |
| 500 | 166 | 250 | 300 | 333 | 357 |
| 600 | 200 | 300 | 360 | 400 | 428 |
| Network db Loss | 6 | 9.5 | 12 | 14 | 15.5 |



$$R_1 = Z_L \left(\frac{N-1}{N+1} \right) \quad \left| \quad \text{Insertion loss in db} = 20 \log_{10} N \right.$$

Where Z_L = identical line and load impedances;
and N = number of channels in parallel.

Minimum Loss Pads



For Matching Two Impedances where $Z_1 > Z_2$

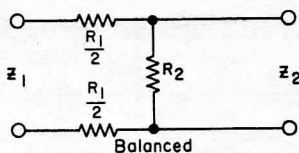
$$R_1 = \sqrt{Z_1 (Z_1 - Z_2)}$$

$$R_2 = \frac{Z_1 Z_2}{R_1}$$

$$\text{db loss} = 20 \log_{10} \left(\sqrt{\frac{Z_1}{Z_2}} + \sqrt{\frac{Z_1}{Z_2} - 1} \right)$$

Where Only One Impedance is to be Matched

If the larger impedance only is to be



matched, use a resistor R_L in series with the smaller impedance such that

$$R_L = Z_1 - Z_2$$

$$\text{db loss} = 20 \log_{10} \sqrt{\frac{Z_1}{Z_2}}$$

If the smaller impedance only is to be matched, use a resistor R_S in shunt across the larger impedance such that

$$R_S = \frac{Z_1 Z_2}{Z_1 - Z_2}$$

$$\text{Here also db loss} = 20 \log_{10} \sqrt{\frac{Z_1}{Z_2}}$$

Tables of R_1 and R_2 Values

When Z_1 is 500 ohms
and Z_2 is less than 500 ohms.

| Z_2 | 400 | 300 | 250 | 200 | 160 | 125 | 100 | 80 | 65 | 50 | 40 | 30 | 25 |
|---------|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|
| R_1 | 224 | 316 | 354 | 387 | 412 | 433 | 447 | 458 | 466 | 474 | 480 | 485 | 487 |
| R_2 | 894 | 474 | 354 | 258 | 194 | 144 | 112 | 87.3 | 69.7 | 52.7 | 41.7 | 30.9 | 25.6 |
| db loss | 4 | 6.5 | 7.5 | 9 | 10 | 11.5 | 12.5 | 13.5 | 14.5 | 16 | 17 | 18 | 19 |

When Z_2 is less than 25 ohms,

$$\text{let } R_1 = 500 - \frac{Z_1}{Z_2}$$

$$\text{and } R_2 = Z_2$$

Where Z_2 is 500 ohms,
and Z_1 is greater than 500 ohms.

| Z_1 | 600 | 800 | 1,000 | 1,200 | 1,500 | 2,000 | 2,500 | 3,000 | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 |
|---------|-------|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| R_1 | 245 | 490 | 707 | 917 | 1,225 | 1,732 | 2,236 | 2,739 | 3,742 | 4,743 | 5,745 | 7,746 | 9,747 |
| R_2 | 1,225 | 817 | 707 | 655 | 612 | 577 | 559 | 548 | 534 | 527 | 522 | 516 | 513 |
| db Loss | 3.5 | 6 | 7.5 | 9 | 10 | 11.5 | 12.5 | 13.5 | 15 | 16 | 17 | 18 | 19 |

When Z_1 is greater than 10,000 ohms,

$$\text{let } R_1 = Z_1 - 250$$

$$\text{and } R_2 = 500$$

70-Volt Loud-Speaker Matching Systems

The RETMA 70.7 volt constant voltage system of power distribution provides the engineer and technician with a simple means of matching a number of loudspeakers to an amplifier. To use this method:

1. Determine the power required at each loudspeaker.
2. Add the powers required for the individual speakers and select an amplifier with a rated power output equal to or greater than this total.
3. Select 70.7-volt transformers having primary wattage taps as determined in step 1.*
4. Wire the selected primaries in parallel across the 70.7-volt line.
5. Connect each secondary to its speaker; selecting the tap which matches the voice coil impedance.

For transformers rated in impedance, the following formulas may be used to determine the proper taps in step 3.

$$\text{Primary Impedance} = \frac{(\text{Amplifier output voltage})^2}{\text{Desired speaker power}}$$

$$\text{or } Z = \frac{E^2}{P} \quad (1)$$

*These transformers have the primary taps marked in watts and the secondaries marked in ohms.

Since the voltage at rated amplifier power is 70.7, this reduces to:

$$Z = \frac{70.7^2}{P} = \frac{5000}{P} \quad (2)$$

From formula (2) these relationships are:

- 1 watt requires 5000 ohm primary
- 2 watts requires 2500 ohm primary
- 5 watts requires 1000 ohm primary
- 10 watts requires 500 ohm primary

Once the primary taps have been determined, continue on through step 4 and 5 as outlined above. When selecting transformer primary taps, use the next highest available value above the computed value. A mismatch of 25% is generally considered permissible.

Example: Required

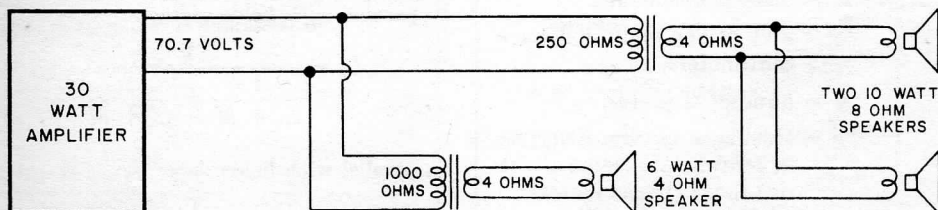
One 6 watt speaker with 4 ohm voice coil.
Two 10 watt speakers with 8 ohm voice coils (use one transformer at this location).

(1-2) Total power = 6 + 10 + 10 = 26 watts (use a 30-watt amplifier or other amplifier capable of handling at least 26 watts)

(3) $Z_{6 \text{ watts}} = \frac{5000}{6} = 833 \text{ ohms}$ (use 1000 ohm transformer)

$Z_{20 \text{ watts}} = \frac{5000}{20} = 250 \text{ ohms}$

(4-5) See sketch below.



Most Used Formulas

Resistance Formulas

In series $R_t = R_1 + R_2 + R_3 \dots \text{etc.}$

In parallel $R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots \text{etc.}}$

Two resistors in parallel $R_t = \frac{R_1 R_2}{R_1 + R_2}$

Capacitance

In parallel $C_t = C_1 + C_2 + C_3 \dots \text{etc.}$

In series $C_t = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \dots \text{etc.}}$

Two capacitors in series $C_t = \frac{C_1 C_2}{C_1 + C_2}$

The Quantity of Electricity Stored Within a Capacitor is Given by

$$Q = CE$$

where Q = the quantity stored, in coulombs,

E = the potential impressed across the condenser, in volts,

C = capacitance in farads.

The Capacitance of a Parallel Plate Capacitor is Given by

$$C = 0.0885 \frac{KS(N-1)}{d}$$

where C = capacitance in mmfd.,

K = dielectric constant,

* S = area of one plate in square centimeters,

N = number of plates,

* d = thickness of the dielectric in centimeters (same as the distance between plates).

* When S and d are given in inches, change constant 0.0885 to 0.224. Answer will still be in micromicrofarads.

DIELECTRIC CONSTANTS

| Kind of Dielectric | Approximate* K Value |
|------------------------------------|-------------------------|
| Air (at atmospheric pressure)..... | 1.0 |
| Bakelite..... | 5.0 |
| Beeswax..... | 3.0 |
| Cambric (varnished)..... | 4.0 |
| Fibre (Red)..... | 5.0 |
| Glass (window or flint)..... | 8.0 |
| Gutta Percha..... | 4.0 |
| Mica..... | 6.0 |
| Paraffin (solid)..... | 2.5 |
| Paraffin Coated Paper..... | 3.5 |
| Porcelain..... | 6.0 |
| Pyrex..... | 4.5 |
| Quartz..... | 5.0 |
| Rubber..... | 3.0 |
| Slate..... | 7.0 |
| Wood (very dry)..... | 5.0 |

* These values are approximate, since true values depend upon quality or grade of material used, as well as moisture content, temperature and frequency characteristics of each.

Self-Inductance

In series $L_t = L_1 + L_2 + L_3 \dots \text{etc.}$

In parallel $L_t = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \dots \text{etc.}}$

Two inductors in parallel $L_t = \frac{L_1 L_2}{L_1 + L_2}$

Coupled Inductance

In series with fields *aiding*

$$L_t = L_1 + L_2 + 2M$$

In series with fields *opposing*

$$L_t = L_1 + L_2 - 2M$$

In parallel with fields *aiding*

$$L_t = \frac{1}{\frac{1}{L_1 + M} + \frac{1}{L_2 + M}}$$

In parallel with fields *opposing*

$$L_t = \frac{1}{\frac{1}{L_1 - M} + \frac{1}{L_2 - M}}$$

where L_t = the total inductance,
 M = the mutual inductance,
 L_1 and L_2 = the self inductance of the individual coils.

Mutual Inductance

The mutual inductance of two r-f coils with fields interacting, is given by

$$M = \frac{L_A - L_O}{4}$$

where M = mutual inductance, expressed in same units as L_A and L_O ,

L_A = Total inductance of coils L_1 and L_2 with fields *aiding*,

L_O = Total inductance of coils L_1 and L_2 with fields *opposing*.

Coupling Coefficient

When two r-f coils are inductively coupled so as to give transformer action, the coupling coefficient is expressed by

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

where K = the coupling coefficient;
 $(K \times 10^2 = \text{coupling coefficient in } \%)$,

M = the mutual inductance value,

L_1 and L_2 = the self-inductance of the two coils respectively, both being expressed in the same units.

Resonance

The resonant frequency, or frequency at which inductive reactance X_L equals capacitive reactance X_C , is expressed by.

$$f_r = \frac{1}{2\pi \sqrt{LC}}$$

$$\text{also } L = \frac{1}{4\pi^2 f_r^2 C}$$

$$\text{and } C = \frac{1}{4\pi^2 f_r^2 L}$$

where f_r = resonant frequency in cycles per second,

L = inductance in henrys,

C = capacitance in farads,

$$2\pi = 6.28$$

$$4\pi^2 = 39.5$$

Reactance

of an inductance is expressed by

$$X_L = 2\pi fL$$

of a capacitance is expressed by

$$X_C = \frac{1}{2\pi fC}$$

where X_L = inductive reactance in ohms, (known as positive reactance),

X_C = capacitive reactance in ohms, (known as negative reactance),

f = frequency in cycles per second,

L = inductance in henrys,

C = capacitance in farads,

$$2\pi = 6.28$$

Frequency from Wavelength

$$f = \frac{3 \times 10^5}{\lambda} \text{ (kilocycles)}$$

where λ = wavelength in *meters*.

$$f = \frac{3 \times 10^4}{\lambda} \text{ (megacycles)}$$

where λ = wavelength in *centimeters*.

Wavelength from Frequency

$$\lambda = \frac{3 \times 10^5}{f} \text{ (meters)}$$

where f = frequency in *kilocycles*.

$$\lambda = \frac{3 \times 10^4}{f} \text{ (centimeters)}$$

where f = frequency in *megacycles*.

Q or Figure of Merit

of a simple reactor

$$Q = \frac{X_L}{R_L}$$

of a single capacitor

$$Q = \frac{X_C}{R_C}$$

where Q = a ratio expressing the figure of merit,

X_L = inductive reactance in ohms,

X_C = capacitive reactance in ohms,

R_L = resistance in ohms acting in series with inductance,

R_C = resistance in ohms acting in series with capacitance,

Impedance

In any a-c circuit where resistance and reactance values of the R , L and C components are given, the absolute or numerical magnitude of impedance and phase angle can be computed from the formulas which follow.

In general the basic formulas expressing total impedance are:

for series circuits,

$$Z_t = \sqrt{R_t^2 + X_t^2};$$

for parallel circuits,

$$Z_t = \frac{1}{\sqrt{G_t^2 + B_t^2}};$$

See page 17 for formulas involving impedance, conductance, susceptance and admittance.

In series circuits where phase angle and any two of the Z , R and X components are known, the unknown component may be determined from the expressions:

$$Z = \frac{R}{\cos \theta} \quad Z = \frac{X}{\sin \theta}$$

$$R = Z \cos \theta \quad X = Z \sin \theta$$

where Z = magnitude of impedance in ohms,

R = resistance in ohms,

X = reactance (inductive or capacitive) in ohms.

Nomenclature

Z = absolute or numerical value of impedance magnitude in ohms

R = resistance in ohms,

X_L = inductive reactance in ohms,

X_C = capacitive reactance in ohms,

L = inductance in henrys,

C = capacitance in farads,

R_L = resistance in ohms acting in series with inductance,

R_C = resistance in ohms acting in series with capacitance,

θ = phase angle in degrees by which current leads voltage in a capacitive circuit, or lags voltage in an inductive circuit. In a resonant circuit, where X_L equals X_C , θ equals 0° .

Degrees $\times 0.0175$ = radians.

1 radian = 57.3° .

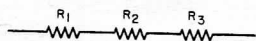
Numerical Magnitude of Impedance . . .



of resistance alone

$$Z = R$$

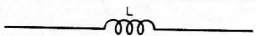
$$\theta = 0^\circ$$



of resistance in series

$$Z = R_1 + R_2 + R_3 \dots \text{etc.}$$

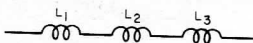
$$\theta = 0^\circ$$



of inductance alone

$$Z = X_L$$

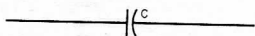
$$\theta = +90^\circ$$



of inductance in series

$$Z = X_{L1} + X_{L2} + X_{L3} \dots \text{etc.}$$

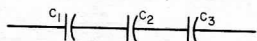
$$\theta = +90^\circ$$



of capacitance alone

$$Z = X_C$$

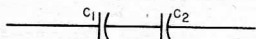
$$\theta = -90^\circ$$



of capacitance in series

$$Z = X_{C1} + X_{C2} + X_{C3} \dots \text{etc.}$$

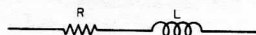
$$\theta = -90^\circ$$



or where only 2 capacitances C_1 and C_2 are involved,

$$Z = \frac{1}{2\pi f} \left(\frac{C_1 + C_2}{C_1 C_2} \right)$$

$$\theta = -90^\circ$$



of resistance and inductance in series

$$Z = \sqrt{R^2 + X_L^2}$$

$$\theta = \arctan \frac{X_L}{R}$$



of resistance and capacitance in series

$$Z = \sqrt{R^2 + X_C^2}$$

$$\theta = \arctan \frac{X_C}{R}$$



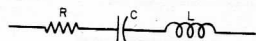
of inductance and capacitance in series

$$Z = X_L - X_C$$

$$\theta = -90^\circ \text{ when } X_L < X_C$$

$$= 0^\circ \text{ when } X_L = X_C$$

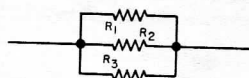
$$= +90^\circ \text{ when } X_L > X_C$$



of resistance, inductance and capacitance in series

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

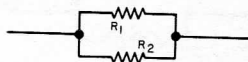
$$\theta = \arctan \frac{X_L - X_C}{R}$$



of resistance in parallel

$$Z = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots \text{etc.}}$$

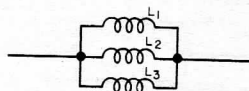
$$\theta = 0^\circ$$



or where only 2 resistances R_1 and R_2 are involved,

$$Z = \frac{R_1 R_2}{R_1 + R_2}$$

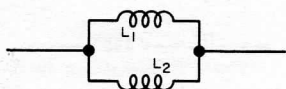
$$\theta = 0^\circ$$



of inductance in parallel

$$Z = \frac{1}{\frac{1}{X_{L1}} + \frac{1}{X_{L2}} + \frac{1}{X_{L3}} \dots \text{etc.}}$$

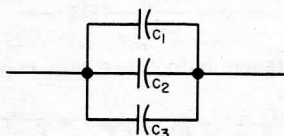
$$\theta = +90^\circ$$



or where only 2 inductances L_1 and L_2 are involved,

$$Z = 2\pi f \left(\frac{L_1 L_2}{L_1 + L_2} \right)$$

$$\theta = +90^\circ$$



of capacitance in parallel

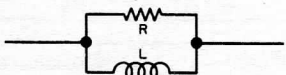
$$Z = \frac{1}{\frac{1}{X_{C1}} + \frac{1}{X_{C2}} + \frac{1}{X_{C3}} \dots \text{etc.}}$$

$$\theta = -90^\circ$$

or where only 2 capacitances C_1 and C_2 are involved,

$$Z = \frac{1}{2\pi f (C_1 + C_2)}$$

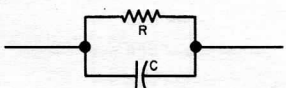
$$\theta = -90^\circ$$



of inductance and resistance in parallel,

$$Z = \frac{RX_L}{\sqrt{R^2 + X_L^2}}$$

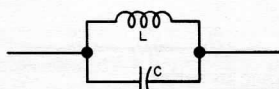
$$\theta = \arctan \frac{R}{X_L}$$



of capacitance and resistance in parallel,

$$Z = \frac{RX_C}{\sqrt{R^2 + X_C^2}}$$

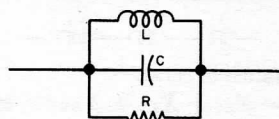
$$\theta = -\arctan \frac{R}{X_C}$$



of inductance and capacitance in parallel,

$$Z = \frac{X_L X_C}{X_L - X_C}$$

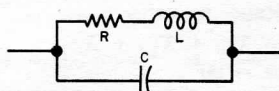
$$\theta = 0^\circ \text{ when } X_L = X_C$$



of inductance, resistance and capacitance in parallel

$$Z = \frac{RX_L X_C}{\sqrt{X_L^2 X_C^2 + (RX_L - RX_C)^2}}$$

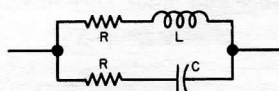
$$\theta = \arctan \frac{RX_C - RX_L}{X_L X_C}$$



of inductance and series resistance in parallel with capacitance

$$Z = X_C \sqrt{\frac{R^2 + X_L^2}{R^2 + (X_L - X_C)^2}}$$

$$\theta = \arctan \left(\frac{X_L X_C - X_L^2 - R^2}{RX_C} \right)$$



of capacitance and series resistance in parallel with inductance and series resistance

$$Z = \sqrt{\frac{(R_L^2 + X_L^2)(R_C^2 + X_C^2)}{(R_L + R_C)^2 + (X_L - X_C)^2}}$$

$$\theta = \arctan \frac{X_L(R_C^2 + X_C^2) - X_C(R_L^2 + X_L^2)}{R_L(R_C^2 + X_C^2) + R_C(R_L^2 + X_L^2)}$$

Conductance

In direct current circuits, conductance is expressed by

$$G = \frac{1}{R}$$

where G = conductance in mhos,

R = resistance in ohms.

In d-c circuits involving resistances R_1 , R_2 , R_3 , etc., in parallel,

the total conductance is expressed by

$$G_{\text{total}} = G_1 + G_2 + G_3 \dots \text{etc.}$$

and the total current by

$$I_{\text{total}} = E G_{\text{total}}$$

and the amount of current in any single resistor, R_2 for example, in a parallel group, by

$$I_2 = \frac{I_{\text{total}} G_2}{G_1 + G_2 + G_3 \dots \text{etc.}}$$

R , E and I in Ohm's law formulas for d-c circuits may be expressed in terms of conductance as follows:

$$R = \frac{1}{G}, \quad E = \frac{I}{G}, \quad I = EG,$$

where G = conductance in mhos,

R = resistance in ohms,

E = potential in volts,

I = current in amperes.

Susceptance

In an alternating current circuit, the susceptance of a series circuit is expressed by

$$B = \frac{X}{R^2 + X^2}$$

or, when the resistance is 0, susceptance becomes the reciprocal of reactance, or

$$B = \frac{1}{X}$$

where B = susceptance in mhos,

R = resistance in ohms,

X = reactance in ohms.

Admittance

In an alternating current circuit, the admittance of a series circuit is expressed by

$$Y = \frac{1}{\sqrt{R^2 + X^2}}$$

Admittance is also expressed as the reciprocal of impedance, or

$$Y = \frac{1}{Z}$$

where Y = admittance in mhos,

R = resistance in ohms,

X = reactance in ohms,

Z = impedance in ohms.

R and X in Terms of G and B

Resistance and reactance may be expressed in terms of conductance and susceptance as follows:

$$R = \frac{G}{G^2 + B^2}, \quad X = \frac{B}{G^2 + B^2}.$$

G, B, Y and Z in Parallel Circuits

In any given a-c circuit containing a number of smaller parallel circuits only,

the effective conductance G_t is expressed by

$$G_t = G_1 + G_2 + G_3 \dots \text{etc.},$$

and the effective susceptance B_t by

$$B_t = B_1 + B_2 + B_3 \dots \text{etc.}$$

and the effective admittance Y_t by

$$Y_t = \sqrt{G_t^2 + B_t^2}$$

and the effective impedance Z_t by

$$Z_t = \frac{1}{\sqrt{G_t^2 + B_t^2}} \text{ or } \frac{1}{Y_t}$$

where R = resistance in ohms,

X = reactance (capacitive or inductive) in ohms,

G = conductance in mhos,

B = susceptance in mhos,

Y = admittance in mhos,

Z = impedance in ohms.

Transient I and E in LCR Circuits

The formulas which follow may be used to closely approximate the growth and decay of current and voltage in circuits involving L , C and R :

where i = instantaneous current in amperes at any given time (t),
 E = potential in volts as designated,
 R = circuit resistance in ohms,
 C = capacitance in farads,
 L = inductance in henrys,
 V = steady state potential in volts,
 V_C = reactive volts across C ,
 V_L = reactive volts across L ,
 V_R = voltage across R

RC = time constant of RC circuit in seconds,

$\frac{L}{R}$ = time constant of RL circuit in seconds,

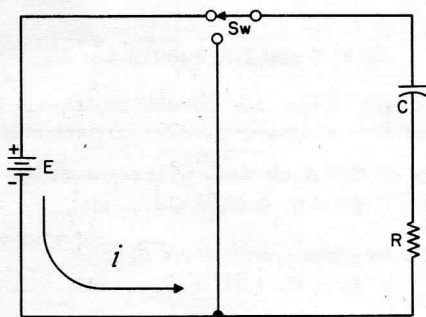
t = any given time in seconds after switch is thrown,

e = a constant, 2.718 (base of the natural system of logarithms),

Sw = switch

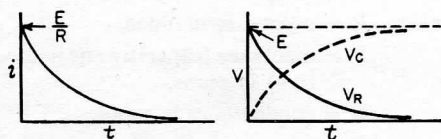
The time constant is defined as the time in seconds for current or voltage to fall to $\frac{1}{e}$ or 36.8% of its initial value or to rise to $(1 - \frac{1}{e})$ or approximately 63.2% of its final value.

Charging a De-energized Capacitive Circuit



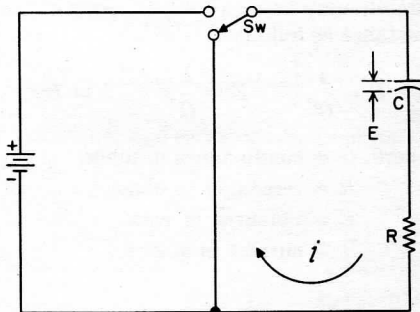
E = applied potential.

$$i = \frac{E}{R} e^{-\frac{t}{RC}}$$



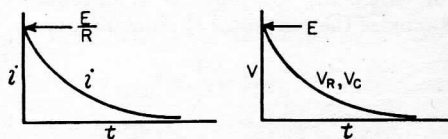
$$V_C = E \left(1 - e^{-\frac{t}{RC}} \right) \quad V_R = E e^{-\frac{t}{RC}}$$

Discharging an Energized Capacitive Circuit



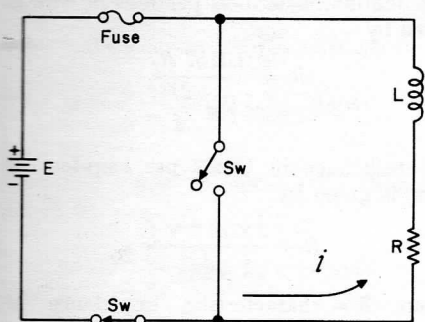
E = potential to which C is charged prior to closing Sw .

$$i = \frac{E}{R} e^{-\frac{t}{RC}}$$



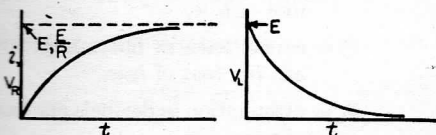
$$V_C = V_R = E e^{-\frac{t}{RC}}$$

Voltage is Applied to a De-energized Inductive Circuit



E = applied potential

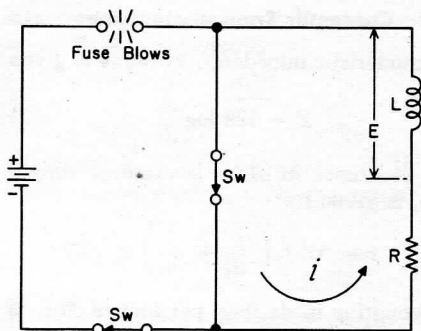
$$i = \frac{E}{R} \left(1 - e^{-\frac{Rt}{L}} \right)$$



$$V_R = E \left(1 - e^{-\frac{Rt}{L}} \right)$$

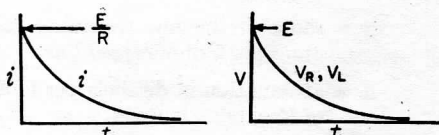
$$V_L = E e^{-\frac{Rt}{L}}$$

An Energized Inductive Circuit is Short Circuited



E = counter potential induced in coil when switch is closed.

$$i = \frac{E}{R} e^{-\frac{Rt}{L}}$$



$$V_L = V_R = E e^{-\frac{Rt}{L}}$$

Steady State Current Flow

In a Capacitive Circuit

In a capacitive circuit, where resistance loss components may be considered as negligible, the flow of current at a given alternating potential of constant frequency, is expressed by

$$I = \frac{E}{X_C} = \frac{E}{\left(\frac{1}{2\pi fC} \right)} = E (2\pi fC)$$

where I = current in amperes,

X_C = capacitive reactance of the circuit in ohms,

E = applied potential in volts.

In an Inductive Circuit

In an inductive circuit, where inherent resistance and capacitance components may be so low as to be negligible, the flow of current at a given alternating potential of a constant frequency, is expressed by

$$I = \frac{E}{X_L} = \frac{E}{2\pi fL}$$

where I = current in amperes,

X_L = inductive reactance of the circuit in ohms,

E = applied potential in volts.

Transmission Line Formulas

Concentric Transmission Lines

Characteristic impedance in ohms is given by

$$Z = 138 \log \frac{d_1}{d_2}$$

R-f resistance in ohms per foot of copper line, is given by

$$r = \sqrt{f} \left(\frac{1}{d_1} + \frac{1}{d_2} \right) \times 10^{-3}$$

Attenuation in decibels per foot of line, is given by

$$a = \frac{4.6\sqrt{f}(d_1 + d_2)}{d_1 d_2 \left(\log \frac{d_1}{d_2} \right)} \times 10^{-6}$$

where Z = characteristic impedance in ohms,

r = radio frequency resistance in ohms per foot of copper line,

a = attenuation in decibels per foot of line,

d_1 = the inside diameter of the outer conductor, expressed in inches,

d_2 = the outside diameter of the inner conductor, expressed in inches,

f = frequency in megacycles.

Two-Wire Open Air Transmission Lines

Characteristic impedance in ohms is given by

$$Z = 276 \left(\log \frac{2D}{d} \right)$$

Inductance in microhenrys per foot of line is given by

$$L = 0.281 \left(\log \frac{2D}{d} \right)$$

Capacitance in micromicrofarads per foot of line is given by

$$C = \frac{3.68}{\log \frac{2D}{d}}$$

Attenuation in decibels per foot of wire is given by

$$db = \frac{0.0157 R_f}{\log \frac{2D}{d}}$$

R-f resistance in Ohms per loop-foot of wire, is given by

$$R_f = \frac{2 \times 10^{-3} \sqrt{f}}{d}$$

where Z = characteristic impedance in ohms,

D = spacing between wire centers in inches,

d = the diameter of the conductors in inches,

L = inductance in microhenrys per foot of line,

C = capacitance in micromicrofarads per foot of line,

db = attenuation in decibels per foot of wire,

R_f = r-f resistance in ohms per loop-foot of wire,

f = frequency in megacycles.

Vertical Antenna

The capacitance of a vertical antenna, shorter than one-quarter wave length at its operating frequency, is given by

$$C_a = \frac{17l}{\left[\left(\log \epsilon \frac{24l}{d} \right) - 1 \right] \left[1 - \left(\frac{fl}{246} \right)^2 \right]}$$

where C_a = capacitance of the antenna in micromicrofarads,

l = height of antenna in feet,

d = diameter of antenna conductor in inches,

f = operating frequency in megacycles,

ϵ = 2.718 (the base of the natural system of logarithms).

Vacuum Tube Formulas and Symbols

Vacuum Tube Constants

Amplification factor (Mu or μ) is given by

$$\mu = \frac{\Delta E_p}{\Delta E_g} \text{ (with } I_p \text{ constant)}$$

Dynamic plate resistance in ohms, is given by

$$r_p = \frac{\Delta E_p}{\Delta I_p} \text{ (with } E_g \text{ constant)}$$

Mutual conductance in mhos, is given by

$$g_m = \frac{\Delta I_p}{\Delta E_g} \text{ (with } E_p \text{ constant)}$$

Vacuum Tube Formulas

Gain per stage is given by

$$\mu \left(\frac{R_L}{R_L + r_p} \right)$$

Voltage output appearing in R_L is given by

$$\mu \left(\frac{E_s R_L}{r_p + R_L} \right)$$

Power output in R_L , is given by

$$R_L \left(\frac{\mu E_s}{r_p + R_L} \right)^2$$

Maximum power output in R_L which results when $R_L = r_p$, is given by

$$\frac{(\mu E_s)^2}{4r_p}$$

Maximum undistorted power output in R_L , which results when $R_L = 2r_p$, is given by

$$\frac{2(\mu E_s)^2}{9r_p}$$

Required cathode biasing resistor in ohms, for a single tube is given by

$$\frac{E_g}{I_k}$$

Vacuum Tube Symbols

Mu or μ = Amplification factor,

r_p = Dynamic plate resistance in ohms,

g_m = Mutual conductance in mhos,

E_p = Plate voltage in volts,

E_g = Grid voltage in volts,

I_p = Plate current in amperes,

R_L = Plate load resistance in ohms,

I_k = Total cathode current in amperes,

E_s = Signal voltage in volts,

Δ = change or variation in value, which may be either an increment (increase), or a decrement (decrease).

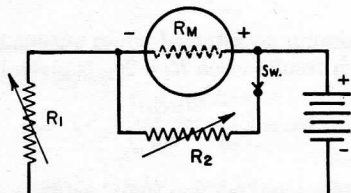
Peak, R.M.S., and Average A-C Values of E & I

| Given Value | To get . . . | | |
|-------------|-----------------------------|----------------------------|----------------------------|
| | Peak | R.M.S. | Av. |
| Peak | | $0.707 \times \text{Peak}$ | $0.637 \times \text{Peak}$ |
| R.M.S. | $1.41 \times \text{R.M.S.}$ | | $0.9 \times \text{R.M.S.}$ |
| Av. | $1.57 \times \text{Av.}$ | $1.11 \times \text{Av.}$ | |

D-C Meter Formulas

Meter Resistance

The d-c resistance of a milliammeter or voltmeter movement may be determined as follows:



1. Connect the meter in series with a suitable battery and variable resistance R_1 as shown in the diagram above.
2. Vary R_1 until a full scale reading is obtained.
3. Connect another variable resistor R_2 across the meter and vary its value until a half scale reading is obtained.
4. Disconnect R_2 from the circuit and measure its d-c resistance.

The meter resistance R_m is equal to the measured resistance of R_2 .

Caution: Be sure that R_1 has sufficient resistance to prevent an off scale reading of the meter. The correct value depends upon the sensitivity of meter, and voltage of the battery. The following formula can be used if the full scale current of the meter is known:

$$R_1 = \frac{\text{voltage of the battery used}}{\text{full scale current of meter in amperes}}$$

For safe results, use twice the value computed. Also, never attempt to measure the resistance of a meter with an ohmmeter. To do so would in all probability result in a burned-out or severely damaged meter, since the current required for the operation of some ohmmeters and bridges is far in excess of the full scale current required by the movement of the average meter you may be checking.

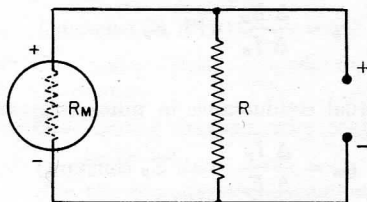
Ohms per Volt Rating of a Voltmeter

$$\Omega/V = \frac{1}{I_{fs}}$$

where Ω/V = ohms per volt,

I_{fs} = full scale current in amperes.

Fixed Current Shunts



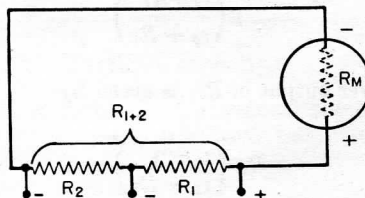
$$R = \frac{R_m}{N - 1}$$

R = shunt value in ohms,

N = the new full scale reading divided by the original full scale reading, both being stated in the same units,

R_m = meter resistance in ohms.

Multi-Range Shunts



$$R_1 = \frac{R_{1+2} + R_m}{N}$$

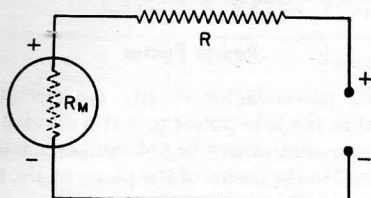
R_1 = intermediate or tapped shunt value in ohms,

R_{1+2} = total resistance required for the lowest scale reading wanted,

R_m = meter resistance in ohms,

N = the new full scale reading divided by the original full scale reading, both being stated in the same units.

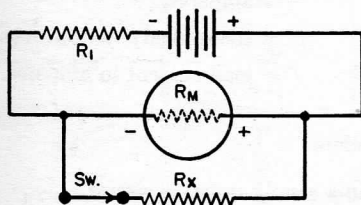
Voltage Multipliers



$$R = \frac{E_{fs}}{I_{fs}} - R_m$$

R = multiplier resistance in ohms,
 E_{fs} = full scale reading required in volts,
 I_{fs} = full scale current of meter in amperes,
 R_m = meter resistance in ohms.

Measuring Resistance



with Milliammeter and Battery*

$$R_x = R_m \left(\frac{I_2}{I_1 - I_2} \right)$$

R_x = unknown resistance in ohms,
 R_m = meter resistance in ohms, or effective meter resistance if a shunted range is used,

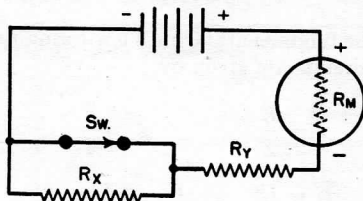
I_1 = current reading with switch open,
 I_2 = current reading with switch closed,
 R_1 = current limiting resistor of sufficient value to keep meter reading on scale when switch is open.

* Approximately true only when current limiting resistor is large as compared to meter resistance.

Shunt Values for 27-Ohm 0-1 Milliammeter

| FULL SCALE CURRENT | SHUNT RESISTANCE |
|--------------------|------------------|
| 0-10 ma | 3.0 ohms |
| 0-50 ma | 0.551 ohms |
| 0-100 ma | 0.272 ohms |
| 0-500 ma | 0.0541 ohms |

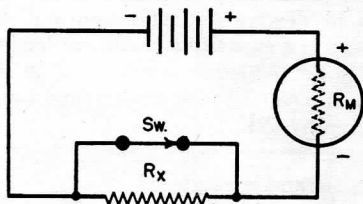
Measuring Resistance—(Continued)



with Milliammeter, Battery and Known Resistor

$$R_x = (R_y + R_m) \left(\frac{I_1 - I_2}{I_2} \right)$$

R_x = unknown resistance in ohms,
 R_y = known resistance in ohms,
 R_m = meter resistance in ohms,
 I_1 = current reading with switch closed,
 I_2 = current reading with switch open.



with Voltmeter and Battery

$$R_x = R_m \left(\frac{E_1}{E_2} - 1 \right)$$

R_x = unknown resistance in ohms,
 R_m = meter resistance in ohms, including multiplier resistance if a multiplied range is used,
 E_1 = voltmeter reading with switch closed,
 E_2 = voltmeter reading with switch open.

Multiplier Values for 27-Ohm 0-1 Milliammeter

| FULL SCALE VOLTAGE | MULTIPLIER RESISTANCE |
|--------------------|-----------------------|
| 0-10 volts | 10,000 ohms |
| 0-50 volts | 50,000 ohms |
| 0-100 volts | 100,000 ohms |
| 0-250 volts | 250,000 ohms |
| 0-500 volts | 500,000 ohms |
| 0-1,000 volts | 1,000,000 ohms |

Ohm's Law for A-C Circuits

The fundamental Ohm's law formulas for a-c circuits are given by

$$I = \frac{E}{Z}, \quad Z = \frac{E}{I},$$

$$E = IZ, \quad P = EI \cos \theta$$

where I = current in amperes,
 Z = impedance in Ohms,
 E = volts across Z ,
 P = power in watts,
 θ = phase angle in degrees.

Phase Angle

The phase angle is defined as the difference in degrees by which current leads voltage in a capacitive circuit, or lags voltage in an inductive circuit, and in series circuits is equal to the angle whose tangent is given by the

ratio $\frac{X}{R}$ and is expressed by

$$\text{arc tan } \frac{X}{R}$$

where X = the inductive or capacitive reactance in ohms,

R = the non-reactive resistance in ohms,

of the combined resistive and reactive components of the circuit under consideration.

Therefore

in a purely resistive circuit, $\theta = 0^\circ$
 in a purely reactive circuit, $\theta = 90^\circ$
 and in a resonant circuit, $\theta = 0^\circ$

also when

$\theta = 0^\circ$, $\cos \theta = 1$ and $P = EI$,
 $\theta = 90^\circ$, $\cos \theta = 0$ and $P = 0$.

Degrees $\times 0.0175$ = radians.
 1 radian = 57.3° .

Power Factor

The power-factor of any a-c circuit is equal to the true power in watts divided by the apparent power in volt-amperes which is equal to the cosine of the phase angle, and is expressed by

$$p.f. = \frac{EI \cos \theta}{EI} = \cos \theta$$

where

$p.f.$ = the circuit load power factor,

$EI \cos \theta$ = the true power in watts,

EI = the apparent power in volt-amperes,

E = the applied potential in volts

I = load current in amperes.

Therefore

in a purely resistive circuit.

$$\theta = 0^\circ \text{ and } p.f. = 1$$

and in a reactive circuit,

$$\theta = 90^\circ \text{ and } p.f. = 0$$

and in a resonant circuit,

$$\theta = 0^\circ \text{ and } p.f. = 1$$

Ohm's Law for D-C Circuits

The fundamental Ohm's law formulas for d-c circuits are given by,

$$I = \frac{E}{R}, \quad R = \frac{E}{I},$$

$$E = IR, \quad P = EI.$$

where I = current in amperes,

R = resistance in ohms,

E = potential across R in volts,

P = power in watts.

Ohm's Law Formulas for D-C Circuits

| Known Values | Formulas for Determining Unknown Values of . . . | | | |
|---------------------|--|-----------------|---------------|-----------------|
| | <i>I</i> | <i>R</i> | <i>E</i> | <i>P</i> |
| <i>I</i> & <i>R</i> | | | IR | I^2R |
| <i>I</i> & <i>E</i> | | $\frac{E}{I}$ | | EI |
| <i>I</i> & <i>P</i> | | $\frac{P}{I^2}$ | $\frac{P}{I}$ | |
| <i>R</i> & <i>E</i> | $\frac{E}{R}$ | | | $\frac{E^2}{R}$ |
| <i>R</i> & <i>P</i> | $\sqrt{\frac{P}{R}}$ | | \sqrt{PR} | |
| <i>E</i> & <i>P</i> | $\frac{P}{E}$ | $\frac{E^2}{P}$ | | |

Ohm's Law Formulas for A-C Circuits

| Known Values | Formulas for Determining Unknown Values of . . . | | | |
|---------------------|--|-----------------------------|---------------------------------|-----------------------------|
| | <i>I</i> | <i>Z</i> | <i>E</i> | <i>P</i> |
| <i>I</i> & <i>Z</i> | | | IZ | $I^2Z \cos \theta$ |
| <i>I</i> & <i>E</i> | | $\frac{E}{I}$ | | $IE \cos \theta$ |
| <i>I</i> & <i>P</i> | | $\frac{P}{I^2 \cos \theta}$ | $\frac{P}{I \cos \theta}$ | |
| <i>Z</i> & <i>E</i> | $\frac{E}{Z}$ | | | $\frac{E^2 \cos \theta}{Z}$ |
| <i>Z</i> & <i>P</i> | $\sqrt{\frac{P}{Z \cos \theta}}$ | | $\sqrt{\frac{PZ}{\cos \theta}}$ | |
| <i>E</i> & <i>P</i> | $\frac{P}{E \cos \theta}$ | $\frac{E^2 \cos \theta}{P}$ | | |

Coil Winding Data

Turns Per Inch

| Gauge (AWG) or (B&S) | Number of Turns per Linear Inch | | | |
|-------------------------------|---------------------------------|--------|-------------------------|--------|
| | Enamel | S.S.C. | D.S.C. and S.C.C. | D.C.C. |
| 1 | — | — | 3.3 | 3.3 |
| 2 | — | — | 3.8 | 3.6 |
| 3 | — | — | 4.2 | 4.0 |
| 4 | — | — | 4.7 | 4.5 |
| 5 | — | — | 5.2 | 5.0 |
| 6 | — | — | 5.9 | 5.6 |
| 7 | — | — | 6.5 | 6.2 |
| 8 | 7.6 | — | 7.4 | 7.1 |
| 9 | 8.6 | — | 8.2 | 7.8 |
| 10 | 9.6 | — | 9.3 | 8.9 |
| 11 | 10.7 | — | 10.3 | 9.8 |
| 12 | 12.0 | — | 11.5 | 10.9 |
| 13 | 13.5 | — | 12.8 | 12.0 |
| 14 | 15.0 | — | 14.2 | 13.8 |
| 15 | 16.8 | — | 15.8 | 14.7 |
| 16 | 18.9 | 18.9 | 17.9 | 16.4 |
| 17 | 21.2 | 21.2 | 19.9 | 18.1 |
| 18 | 23.6 | 23.6 | 22.0 | 19.8 |
| 19 | 26.4 | 26.4 | 24.4 | 21.8 |
| 20 | 29.4 | 29.4 | 27.0 | 23.8 |
| 21 | 33.1 | 32.7 | 29.8 | 26.0 |
| 22 | 37.0 | 36.5 | 34.1 | 30.0 |
| 23 | 41.3 | 40.6 | 37.6 | 31.6 |
| 24 | 46.3 | 45.3 | 41.5 | 35.6 |
| 25 | 51.7 | 50.4 | 45.6 | 38.6 |
| 26 | 58.0 | 55.6 | 50.2 | 41.8 |
| 27 | 64.9 | 61.5 | 55.0 | 45.0 |
| 28 | 72.7 | 68.6 | 60.2 | 48.5 |
| 29 | 81.6 | 74.8 | 65.4 | 51.8 |
| 30 | 90.5 | 83.3 | 71.5 | 55.5 |
| 31 | 101. | 92.0 | 77.5 | 59.2 |
| 32 | 113. | 101. | 83.6 | 62.6 |
| 33 | 127. | 110. | 90.3 | 66.3 |
| 34 | 143. | 120. | 97.0 | 70.0 |
| 35 | 158. | 132. | 104. | 73.5 |
| 36 | 175. | 143. | 111. | 77.0 |
| 37 | 198. | 154. | 118. | 80.3 |
| 38 | 224. | 166. | 126. | 83.6 |
| 39 | 248. | 181. | 133. | 86.6 |
| 40 | 282. | 194. | 140. | 89.7 |

Coil Winding Formulas

The following approximations for winding *r-f* coils are accurate to within approx. 1% for nearly all small air-core coils, where

L = self inductance in microhenrys,

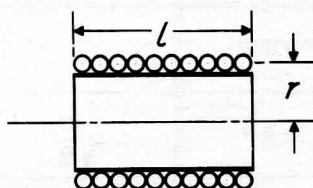
N = total number of turns,

r = mean radius in inches,

l = length of coil in inches,

b = depth of coil in inches.

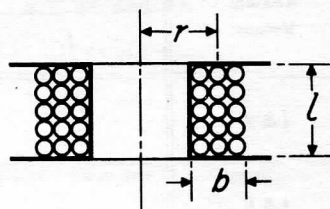
Single-Layer Wound Coils



$$L = \frac{(rN)^2}{9r + 10l}$$

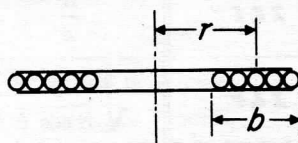
$$N = \frac{\sqrt{L(9r + 10l)}}{r}$$

Multi-Layer Wound Coils



$$L = \frac{0.8(rN)^2}{6r + 9l + 10b}$$

Single-Layer Spiral Wound Coils



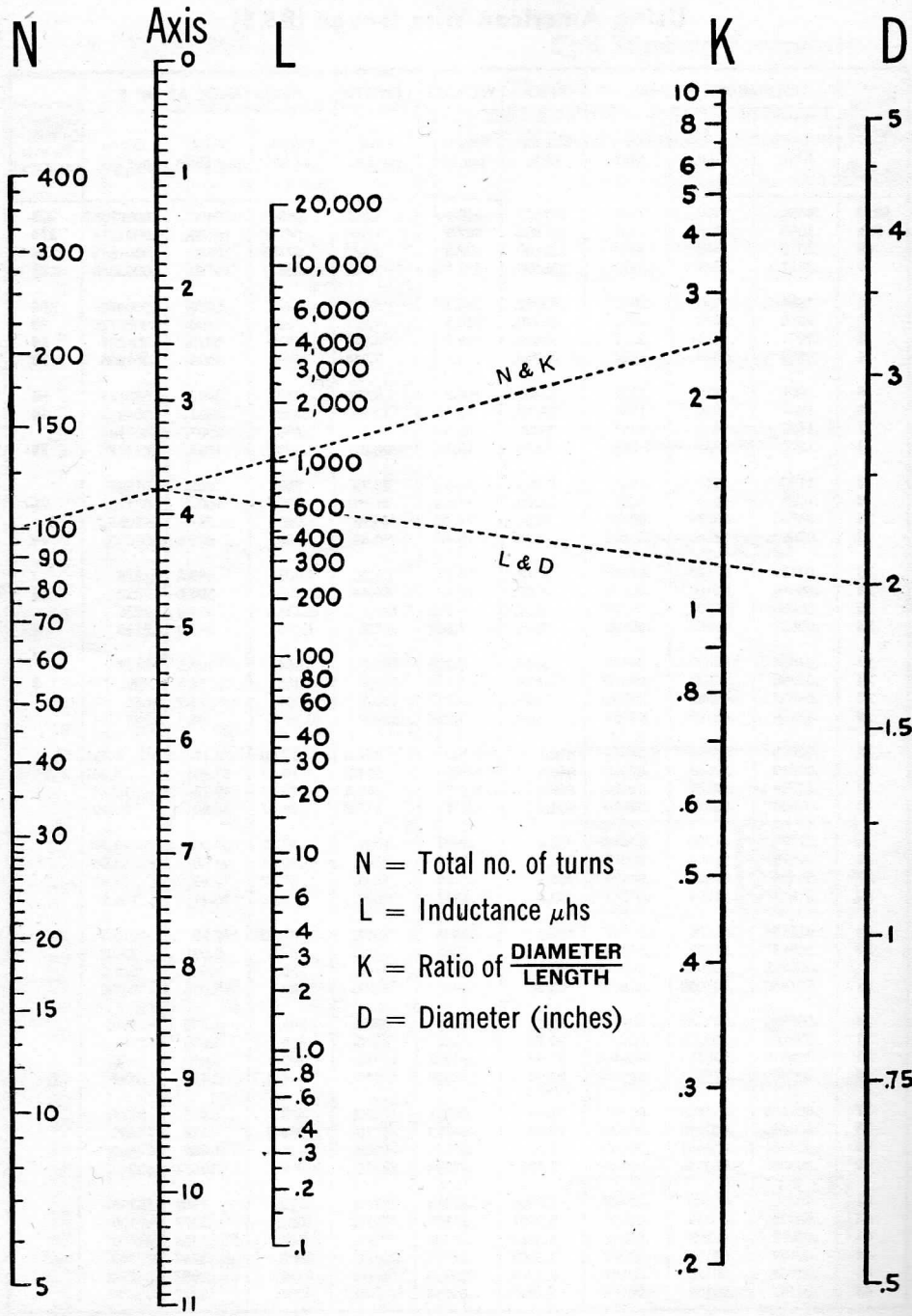
$$L = \frac{(rN)^2}{8r + 11b}$$

**Table of Standard Annealed Bare Copper Wire
Using American Wire Gauge (B & S)**

| Gauge (AWG) or (B & S) | DIAMETER INCHES | | | AREA | WEIGHT | LENGTH | RESISTANCE AT 68° F | | | Current* Capacity (Amps) Rubber Insulated |
|---------------------------------|-----------------|---------|---------|------------------|------------------|-----------------|---------------------|-----------------|-----------------|---|
| | Min. | Nom. | Max. | Circular Mils | Pounds per M' | Feet per Lb. | Ohms per M' | Feet per Ohm | Ohms per Lb. | |
| 0000 | .4554 | .4600 | .4646 | 211600. | 640.5 | 1.561 | .04901 | 20400. | .00007652 | 225 |
| 000 | .4055 | .4096 | .4137 | 167800. | 507.9 | 1.968 | .06180 | 16180. | .0001217 | 175 |
| 00 | .3612 | .3648 | .3684 | 133100. | 402.8 | 2.482 | .07793 | 12830. | .0001935 | 150 |
| 0 | .3217 | .3249 | .3281 | 105500. | 319.5 | 3.130 | .09827 | 10180. | .0003076 | 125 |
| 1 | .2864 | .2893 | .2922 | 83690. | 253.3 | 3.947 | .1239 | 8070. | .0004891 | 100 |
| 2 | .2550 | .2576 | .2602 | 66370. | 200.9 | 4.977 | .1563 | 6400. | .0007778 | 90 |
| 3 | .2271 | .2294 | .2317 | 52640. | 159.3 | 6.276 | .1970 | 5075. | .001237 | 80 |
| 4 | .2023 | .2043 | .2063 | 41740. | 126.4 | 7.914 | .2485 | 4025. | .001966 | 70 |
| 5 | .1801 | .1819 | .1837 | 33100. | 100.2 | 9.980 | .3133 | 3192. | .003127 | 55 |
| 6 | .1604 | .1620 | .1636 | 26250. | 79.46 | 12.58 | .3951 | 2531. | .004972 | 50 |
| 7 | .1429 | .1443 | .1457 | 20820. | 63.02 | 15.87 | .4982 | 2007. | .007905 | |
| 8 | .1272 | .1285 | .1298 | 16510. | 49.98 | 20.01 | .6282 | 1592. | .01257 | 35 |
| 9 | .1133 | .1144 | .1155 | 13090. | 39.63 | 25.23 | .7921 | 1262. | .01999 | |
| 10 | .1009 | .1019 | .1029 | 10380. | 31.43 | 31.82 | .9989 | 1001. | .03178 | 25 |
| 11 | .08983 | .09074 | .09165 | 8234. | 24.92 | 40.12 | 1.260 | 794. | .05053 | |
| 12 | .08000 | .08081 | .08162 | 6530. | 19.77 | 50.59 | 1.588 | 629.6 | .08035 | 20 |
| 13 | .07124 | .07196 | .07268 | 5178. | 15.68 | 63.80 | 2.003 | 499.3 | .1278 | |
| 14 | .06344 | .06408 | .06472 | 4107. | 12.43 | 80.44 | 2.525 | 396.0 | .2032 | 15 |
| 15 | .05650 | .05707 | .05764 | 3257. | 9.858 | 101.4 | 3.184 | 314.0 | .3230 | |
| 16 | .05031 | .05082 | .05133 | 2583. | 7.818 | 127.9 | 4.016 | 249.0 | .5136 | 6 |
| 17 | .04481 | .04526 | .04571 | 2048. | 6.200 | 161.3 | 5.064 | 197.5 | .8167 | |
| 18 | .03990 | .04030 | .04070 | 1624. | 4.917 | 203.4 | 6.385 | 156.5 | 1.299 | 3 |
| 19 | .03553 | .03589 | .03625 | 1288. | 3.899 | 256.5 | 8.051 | 124.2 | 2.065 | |
| 20 | .03164 | .03196 | .03228 | 1022. | 3.092 | 323.4 | 10.15 | 98.5 | 3.283 | |
| 21 | .02818 | .02846 | .02874 | 810.1 | 2.452 | 407.8 | 12.80 | 78.11 | 5.221 | |
| 22 | .02510 | .02535 | .02560 | 642.4 | 1.945 | 514.2 | 16.14 | 61.95 | 8.301 | |
| 23 | .02234 | .02257 | .02280 | 509.5 | 1.542 | 648.4 | 20.36 | 49.13 | 13.20 | |
| 24 | .01990 | .02010 | .02030 | 404.0 | 1.223 | 817.7 | 25.67 | 38.96 | 20.99 | |
| 25 | .01770 | .01790 | .01810 | 320.4 | .9699 | 1031. | 32.37 | 30.90 | 33.37 | |
| 26 | .01578 | .01594 | .01610 | 254.1 | .7692 | 1300. | 40.81 | 24.50 | 53.06 | |
| 27 | .01406 | .01420 | .01434 | 201.5 | .6100 | 1639. | 51.47 | 19.43 | 84.37 | |
| 28 | .01251 | .01264 | .01277 | 159.8 | .4837 | 2067. | 64.90 | 15.41 | 134.2 | |
| 29 | .01115 | .01126 | .01137 | 126.7 | .3836 | 2607. | 81.83 | 12.22 | 213.3 | |
| 30 | .00993 | .01003 | .01013 | 100.5 | .3042 | 3287. | 103.2 | 9.691 | 339.2 | |
| 31 | .008828 | .008928 | .009028 | 79.7 | .2413 | 4145. | 130.1 | 7.685 | 539.3 | |
| 32 | .007850 | .007950 | .008050 | 63.21 | .1913 | 5227. | 164.1 | 6.095 | 857.6 | |
| 33 | .006980 | .007080 | .007180 | 50.13 | .1517 | 6591. | 206.9 | 4.833 | 1364. | |
| 34 | .006205 | .006305 | .006405 | 39.75 | .1203 | 8310. | 260.9 | 3.833 | 2168. | |
| 35 | .005515 | .005615 | .005715 | 31.52 | .09542 | 10480. | 329.0 | 3.040 | 3448. | |
| 36 | .004900 | .005000 | .005100 | 25.00 | .07568 | 13210. | 414.8 | 2.411 | 5482. | |
| 37 | .004353 | .004453 | .004553 | 19.83 | .06001 | 16660. | 523.1 | 1.912 | 8717. | |
| 38 | .003865 | .003965 | .004065 | 15.72 | .04759 | 21010. | 659.6 | 1.516 | 13860. | |
| 39 | .003431 | .003531 | .003631 | 12.47 | .03774 | 26500. | 831.8 | 1.202 | 22040. | |
| 40 | .003045 | .003145 | .003245 | 9.888 | .02993 | 33410. | 1049. | 0.9534 | 35040. | |
| 41 | .00270 | .00280 | .00290 | 7.8400 | .02373 | 42140. | 1323. | .7559 | 55750. | |
| 42 | .00239 | .00249 | .00259 | 6.2001 | .01877 | 53270. | 1673. | .5977 | 89120. | |
| 43 | .00212 | .00222 | .00232 | 4.9284 | .01492 | 67020. | 2104. | .4753 | 141000. | |
| 44 | .00187 | .00197 | .00207 | 3.8809 | .01175 | 85100. | 2672. | .3743 | 227380. | |
| 45 | .00166 | .00176 | .00186 | 3.0976 | .00938 | 106600. | 3348. | .2987 | 356890. | |
| 46 | .00147 | .00157 | .00167 | 2.4649 | .00746 | 134040. | 4207. | .2377 | 563900. | |

*Note: Values from National Electrical Code.

Single-Layer Wound Coil Chart



Courtesy, P. R. Mallory & Co., Inc.

Single-Layer Wound Coil Chart

The chart on the opposite page provides a convenient means of determining the unknown factors of small sized single-layer wound r-f coils. Values thus found so closely approximate those determined by measurement or mathematical calculation as to be entirely satisfactory for all practical purposes of experimentation, design, and repair work. Since in all coils of this type, the difference between the mean and inner diameter of the winding is so slight as to be negligible, D in all instances may be either the mean or inner diameter as desired.

Example: Given the total number of turns, winding length and diameter of a coil,— to find the inductance;

1. Place a straightedge on the chart so as to form a line intersecting the number of turns N , and the ratio of diameter to length K , and note the point intersected on the linear axis column.

2. Now move the straightedge so as to form a second line which will intersect this same point on the axis column, and the diameter D .
3. The point where this line intersects the L column indicates the inductance of the coil in microhenries.

Example: Given the diameter, winding length and inductance in microhenries,— to find the number of turns;

1. Simply reverse the process outlined above for determining inductance.
2. After finding the number of turns, consult the wire table on page 26 and determine the size of wire to be used.

The dotted lines appearing on the chart illustrate the correct plotting of a 600-microhenry coil consisting of 100 turns of wire, wound to 51/64" on a form 2" in diameter.

Inductance, Capacitance, Reactance Charts

The direct-reading charts appearing on the following three pages are designed for determining unknown values of frequency, inductance, capacitance and reactance components operating in a-f and r-f circuits.

The simplifications embodied in these charts make them extremely useful. The frequency range covered comprises the frequency spectrum from 1 cycle per second up to 1000 megacycles per second. All of the scales involved are plotted in actual magnitudes so that no computations are required to determine the location of the decimal point in the final result.

To make these conditions possible the frequency spectrum has been divided into three parts:

Chart I (page 30)—Covers the range from 1 cycle to 1000 cycles.

Chart II (page 31)—From 1 kilocycle to 1000 kilocycles.

Chart III (page 32)—From 1 megacycle to 1000 megacycles.

Inductance, capacitance, reactance and frequency have been plotted so that the reactance offered by an inductance or capacitance at any frequency may be readily determined by placing a straight-edge across the chart connecting the known quantities.

Since $X_L = X_C$ at resonance in most radio circuits, the charts may also be used to find the resonant frequency of any combination of L and C .

To illustrate with a simple example, suppose the reactance of a 0.01 μ f. capacitor is desired at a frequency of 400 cycles. Place a straight-edge across the proper chart so as to connect the points 0.01 μ f. and 400 cycles per sec. The quantity desired is the point of intersection with the reactance scale which is 40,000 ohms. The straight-edge also intersects the inductance scale at 15.8 henrys indicating that this value of inductance likewise has a reactance of 40,000 ohms at 400 cycles per sec. and furthermore, that these values of L and C produce resonance at this frequency.

There are many practical uses for these charts. The radio experimenter, maintenance man and engineer will find them helpful in the rapid solution of many reactance problems. Unusual care was exercised in laying out the various scales in order to secure a high degree of accuracy for the charts. Results should be obtainable which are at least as accurate as might be secured with a ten-inch slide rule.

Inductance, Capacitance, Reactance—(Continued)

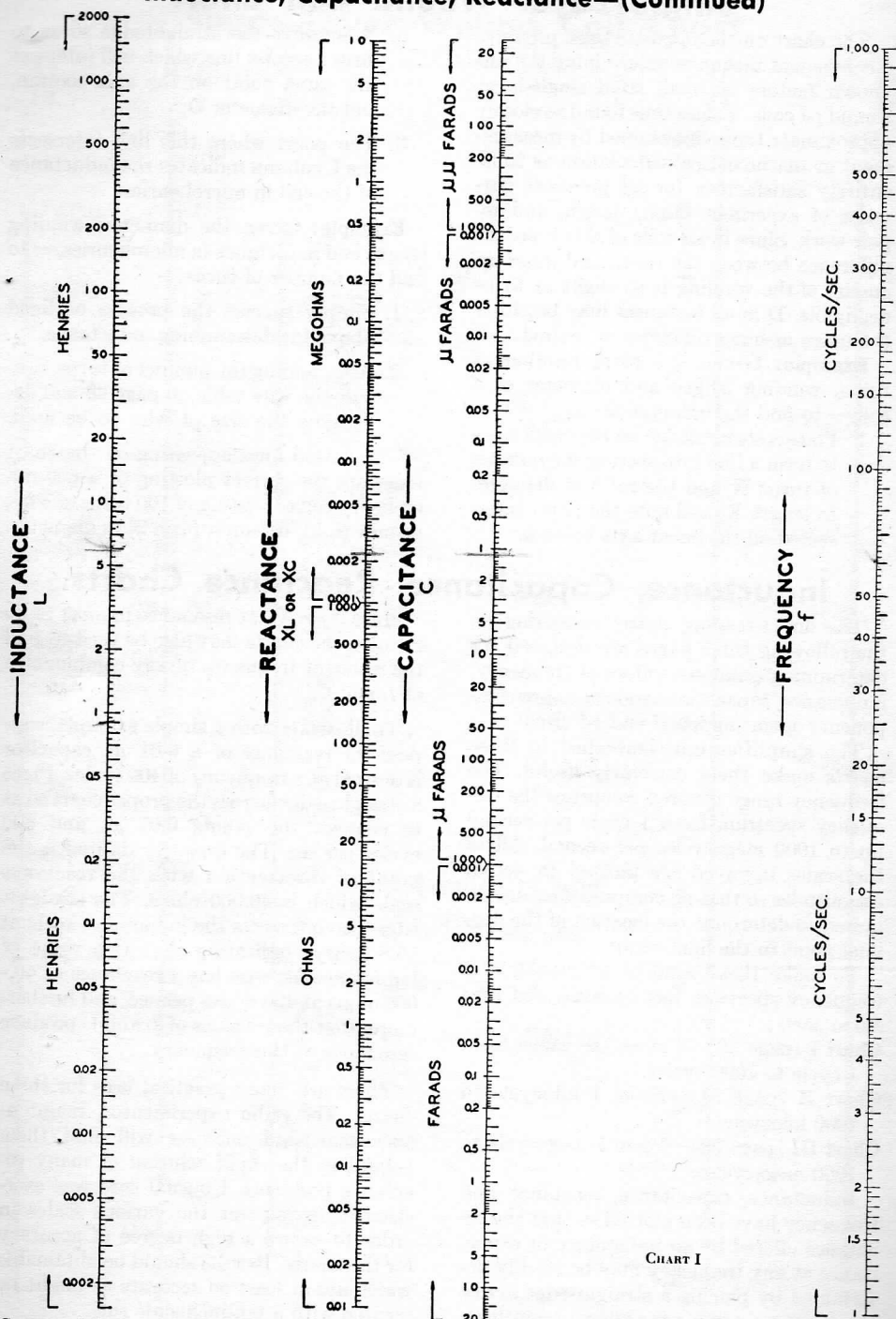


CHART I

Inductance, Capacitance, Reactance—(Continued)

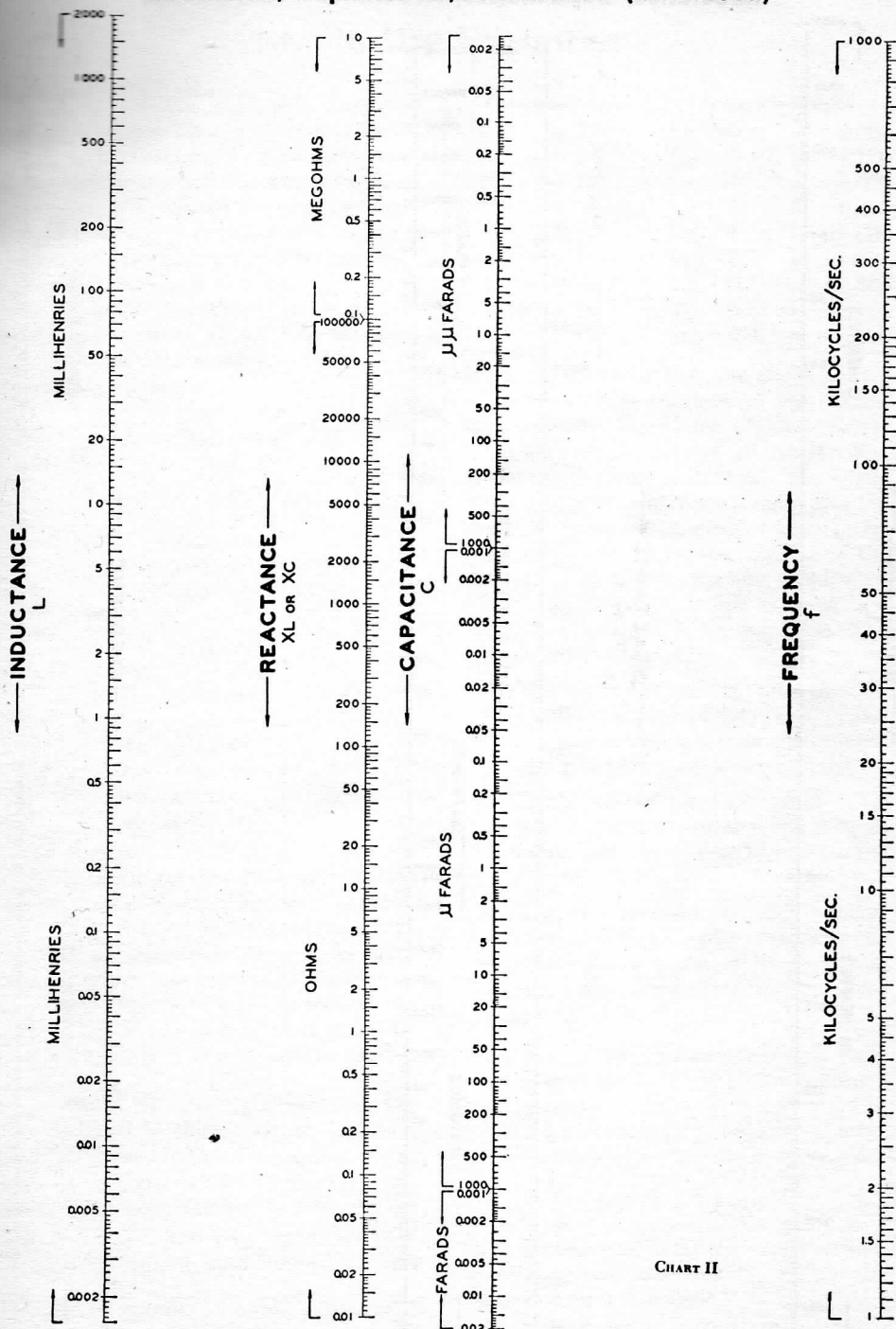


CHART II

Courtesy, Sylvania Electric Products Inc.

Inductance, Capacitance, Reactance—(Continued)

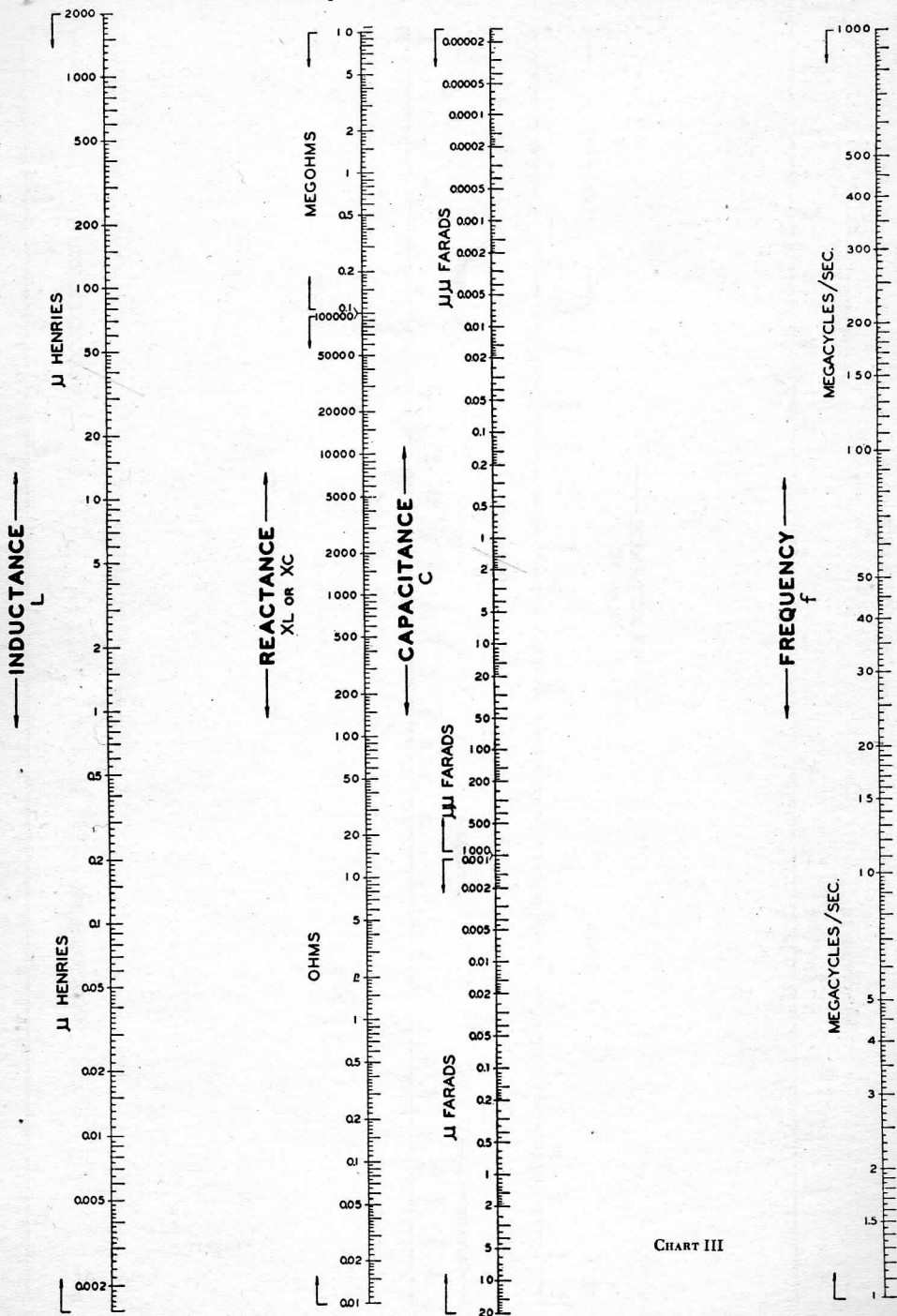


CHART III

Courtesy, Sylvania Electric Products Inc.

How to Use Logarithms

Logarithms are used to simplify numerical computations involving multiplications, division, powers and roots. With logarithms, multiplication is reduced to simple addition, and division is reduced to simple subtraction. Raising to a power is reduced to a single multiplication, and extracting a root is reduced to a single division.

The common logarithm of any number is the power to which 10 must be raised in order to equal that number.

Therefore, since

$$\begin{aligned} 1000 &= 10^3 \\ 100 &= 10^2 \\ 10 &= 10^1 \\ 1 &= 10^0 \\ 0.1 &= 10^{-1} \\ 0.01 &= 10^{-2} \\ 0.001 &= 10^{-3} \\ 0.0001 &= 10^{-4} \end{aligned}$$

it is true that

$$\begin{aligned} \log 1000 &= 3 \\ \log 100 &= 2 \\ \log 10 &= 1 \\ \log 1 &= 0 \\ \log 0.1 &= -1 \\ \log 0.01 &= -2 \\ \log 0.001 &= -3 \\ \log 0.0001 &= -4 \end{aligned}$$

The common system of logarithms has for its base the number 10, and is written \log_{10} or more commonly \log , since the base 10 is always implied unless some other base is specifically indicated. There are formulas however which use the natural system of logarithms. This system has for its base the number 2.718... which is represented by the Greek letter e and is always written $\log e$.

A table of natural logarithms has not been included in this handbook however, since the common log of a number is approximately equal to 2.3026 times the natural log of the same number. Conversely, the natural log of a number is approximately equal to 0.4343 times the common log of the same number.

In observing the following exponential and logarithmic relationships,

| Exponential Form | | Logarithmic Form | |
|------------------|-----------------|------------------|------------|
| 100 | $= 10^2$ | $\log 100$ | $= 2.000$ |
| 15 | $= 10^{1.176}$ | $\log 15$ | $= 1.176$ |
| 10 | $= 10^1$ | $\log 10$ | $= 1.000$ |
| 7 | $= 10^{.845}$ | $\log 7$ | $= 0.845$ |
| 1 | $= 10^0$ | $\log 1$ | $= 0.000$ |
| 0.1 | $= 10^{-1}$ | $\log 0.1$ | $= -1.000$ |
| 0.7 | $= 10^{-1.845}$ | $\log 0.7$ | $= -1.845$ |
| 0.15 | $= 10^{-2.176}$ | $\log 0.15$ | $= -2.176$ |
| 0.001 | $= 10^{-3}$ | $\log 0.001$ | $= -3.000$ |

it will be seen that only the direct powers of 10 have whole numbers for logarithms; also that the logarithms of all numbers lying between a power of 10, consist of a whole number and a decimal. The whole number is called the characteristic, and the decimal, the mantissa. Since the characteristic serves only to fix the location of the decimal point in the expression indicated by the log, it can be found by inspection and is not included in the log table. The following will be helpful:

1. The characteristic of any number greater than 1 is always positive and is equal to one less than the number of digits to the left of the decimal.
2. The characteristic of any number less than 1 is always negative and is equal to one plus the number of zeros to the decimal.
3. The characteristic of any number may be determined by expressing the number as a power of 10 and using this power as the characteristic of the logarithm for that number.

Since only the characteristic of a logarithm is ever negative, the mantissa always being a positive number, it is customary to write a log containing a negative characteristic as follows:

$$\log 0.7 = \bar{1}.845,$$

or, by adding +10 to the characteristic and, in order to maintain equality, -10 at the right of the characteristic,

$$\log 0.7 = 9.845 - 10$$

Examples:

| | | |
|--------|----------------------|--------------|
| 150 | 1.5×10^2 | 2 |
| 15 | 1.5×10^1 | 1 |
| 1.5 | 1.5×10^0 | 0 |
| 0.15 | 1.5×10^{-1} | -1 or 9 - 10 |
| 0.015 | 1.5×10^{-2} | -2 or 8 - 10 |
| 0.0015 | 1.5×10^{-3} | -3 or 7 - 10 |

Therefore, to find the logarithm of any number:

1. Write the number as a power of 10, and put down the resulting exponent of 10 as the characteristic.
2. Determine the mantissa from the log tables on page 56, and write this as a decimal figure following the characteristic.
3. If the resulting logarithm has a negative characteristic, change this to the positive form.

Example: Find the logarithm of .00623:

Since $.00623 = 6.23 \times 10^{-3}$, the characteristic is -3. The mantissa as shown by the log table is 7945. The resultant logarithm = 3.7945 or when written in its positive form, 7.7945 - 10.

To find the log of any number having more than three significant figures (by interpolation):

1. Determine the characteristic.
2. Find the mantissa corresponding to the first three significant figures.
3. Find the next higher mantissa and take the tabular difference.
4. Find the product of the tabular difference and the digit following the first three significant figures of the given number written as a decimal.
5. Add this product to the lesser mantissa.

Example: Find the logarithm of 54.65.

Since $54.65 = 5.465 \times 10^1$, the characteristic is 1.

Next higher mantissa = .7380

Next lower mantissa = .7372

Tabular difference = .0008

| | |
|----------------------|-------------|
| | $\times .5$ |
| Product | .00040 |
| Plus lesser mantissa | .7372 |
| Mantissa of 5.465 | .7376 |

$\therefore \log 54.65 = 1.7376$

Although a four-place log table is used here, for purposes where accuracy to 3 significant figures is required, generally, a three place table is sufficiently accurate for all practical purposes. Since the mantissa of a logarithm represents only the significant figures of any number, the same mantissa is used for .04, 4, 400, etc., the decimal point being fixed later by the characteristic. Therefore any number consisting of 1 or 2 significant figures may be found in the column marked **N**, and its mantissa will be found on the same line in this column headed by **0**. For any number containing 3 significant figures, locate the first two figures in the **N** column, and the third figure in the column headed by the corresponding digit. The mantissa will be found in this column, on a line even with the first two digits.

Example:

| | | |
|-----|-------|---------------|
| log | 21 | = 1.3222 |
| log | 2.1 | = 0.3222 |
| log | 210 | = 2.3222 |
| log | .0021 | = 7.3222 - 10 |
| log | 213 | = 2.3284 |
| log | .0213 | = 9.3284 - 10 |
| log | 3 | = 0.4771 |
| log | 300 | = 2.4771 |
| log | .003 | = 7.4771 - 10 |

The number corresponding to a given logarithm is called the antilogarithm, and is written "antilog". Example: Since $\log 692 = 2.8401$, the antilog of 2.8401 = 692.

Finding the antilog of a number is the reverse of finding the logarithm. First locate the mantissa in the log table, and determine its corresponding number. Now, place the decimal as indicated by the characteristic.

Example: To find the antilog of 3.9138, look up 9138 in the log table. Its corresponding number is 82, or expressed as a power of 10, equals 8.2×10^0 . A characteristic of 3 means that 8.2 must be multiplied by 10^3 . Therefore, $\text{antilog } 3.9138 = 8.2 \times 10^3 = 8200$.

Similarly

$\text{Antilog } 5.9138 = 8.2 \times 10^5 = 82,0000$

$\text{Antilog } 0.9138 = 8.2 \times 10^0 = 8.2$

$\text{Antilog } 7.9138 - 10 = 8.2 \times 10^{-3} = 0.0082$

$\text{Antilog } 9.9138 - 10 = 8.2 \times 10^{-1} = 0.82$

To find the antilogarithm of a logarithm

whose mantissa is not exactly given in the table.

1. Find the tabular difference between the next highest and next lowest mantissas.
2. Divide this by the difference between the given mantissa and the next lowest mantissa.
3. Add the resulting quotient to the significant figures expressed by the next lower mantissa.
4. Place the decimal as indicated by the given characteristic.

Example: Find the antilog of 1.7376

Next higher mantissa .7380

Next lower mantissa .7372

Tabular difference .0008

Given mantissa .7376

Next lower mantissa .7372

Tabular difference .0004

Quotient of $\frac{.0004}{.0008} = .5$

The resultant figure therefore is .5 larger than the significant figures expressed by the lesser mantissa .7372 or 546. The sequence of figures therefore is 546.5

∴ the antilog of 1.7376 = 54.65

NOTE: When interpolating as shown above, do not exceed four significant figures in your answer since interpolated results from a four-place table are not accurate beyond this point.

Logarithms are added or subtracted like arithmetical numbers, provided they are written with positive characteristics. If the characteristic in the total is greater than 9, and the notation -10, -20, -30, etc., appears after the mantissa, subtract a multiple of 10 from the positive part and add the same multiple of 10 to the negative part, so as to make the resultant characteristic less than 10.

EXAMPLES:

Addition of logarithms

| | | |
|-------|-------------|-------------|
| 2.764 | 6.326 - 10 | 6.328 - 10 |
| 4.304 | 6.284 | 7.764 - 10 |
| 7.068 | 12.610 - 10 | 9.104 - 10 |
| | or | 23.196 - 30 |
| | 2.610 | or |
| | | 3.196 - 10 |

Subtraction of logarithms

$$\begin{array}{r} 4.107 \\ 6.986 \end{array} \left\{ \begin{array}{l} 14.107 - 10 \\ = 6.986 \\ \hline 7.121 - 10 \\ 11.672 - 10 \\ 5.785 - 10 \\ \hline 5.887 \end{array} \right.$$

The relationships of logarithmic operations are expressed by the following formulas:

$$\log (a \times b) = \log a + \log b$$

$$\log \left(\frac{a}{b} \right) = \log a - \log b$$

$$\log (a)^b = b \log a$$

$$\log \sqrt[b]{a} = \frac{\log a}{b}$$

EXAMPLES

To Multiply 1.24 by 246

$$\log \text{ of } 1.24 = 0.0934$$

$$\log \text{ of } 246 = 2.3909$$

$$\text{Total } 2.4843$$

The antilog of 2.4843 = 305, which is as accurate as can be determined with a four-place table. The full answer to this problem is 305.04.

To Divide 961 by 224

$$\log \text{ of } 961 = 2.9827$$

$$\log \text{ of } 224 = 2.3502$$

$$\text{Difference } 0.6325$$

The antilog of 0.6325 = 4.29 which is as accurate as can be determined with a four-place table. The product of 224 and 4.29 is 960.96.

Powers: Find 12^2 by logarithms:

$$\log \text{ of } 12 = 1.0792$$

$$\times 2$$

$$2.1584$$

The antilog of 2.1584 = 144.

Roots

Find $\sqrt[3]{343}$

$$\log \text{ of } 343 = 2.5353 \div 3 = .8451$$

The antilog of .8451 = 7.

Logarithms of Negative Numbers. Because the logarithms of negative numbers are imaginary in character, they cannot be used in computation as with positive numbers. However, since the numerical results of multiplying, dividing, etc., are not affected by the signs, you can determine the numerical results by logarithms and later affix the final + or - signs by inspection.

Trigonometric Relationships

In any right triangle, if we let

θ = the acute angle formed by the hypotenuse and the base leg,

ϕ = the acute angle formed by the hypotenuse and the altitude leg,

H = the hypotenuse,

A = the side adjacent θ and opposite ϕ ,

O = the side opposite θ and adjacent ϕ ,

then $\sin \theta = \frac{O}{H}$

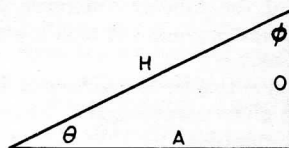
$\cos \theta = \frac{A}{H}$

$\tan \theta = \frac{O}{A}$

$\csc \theta = \frac{H}{O}$

$\sec \theta = \frac{H}{A}$

$\cot \theta = \frac{A}{O}$



also

$$\sin \theta = \cos \phi \quad \csc \theta = \sec \phi$$

$$\cos \theta = \sin \phi \quad \sec \theta = \csc \phi$$

$$\tan \theta = \cot \phi \quad \cot \theta = \tan \phi$$

and

$$\frac{1}{\sin \theta} = \csc \theta \quad \frac{1}{\csc \theta} = \sin \theta$$

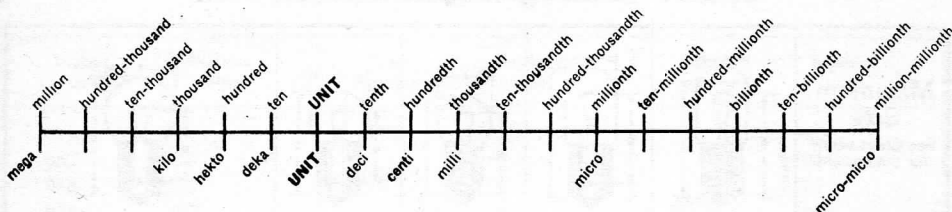
$$\frac{1}{\cos \theta} = \sec \theta \quad \frac{1}{\sec \theta} = \cos \theta$$

$$\frac{1}{\tan \theta} = \cot \theta \quad \frac{1}{\cot \theta} = \tan \theta$$

The expression "arc sin" indicates, "the angle whose sine is" . . . ; likewise arc tan indicates, "the angle whose tangent is" . . . etc. See formulas in table below.

| Known Values | Formulas for Determining Unknown Values of . . . | | | | |
|--------------|--|-----------------------|-------------------------|-----------------------|-----------------------|
| | A | O | H | θ | ϕ |
| A & O | | | $\sqrt{A^2 + O^2}$ | $\arctan \frac{O}{A}$ | $\arctan \frac{A}{O}$ |
| A & H | | $\sqrt{H^2 - A^2}$ | | $\arccos \frac{A}{H}$ | $\arcsin \frac{A}{H}$ |
| A & θ | | $A \tan \theta$ | $\frac{A}{\cos \theta}$ | | $90^\circ - \theta$ |
| A & ϕ | | $\frac{A}{\tan \phi}$ | $\frac{A}{\sin \phi}$ | $90^\circ - \phi$ | |
| O & H | $\sqrt{H^2 - O^2}$ | | | $\arcsin \frac{O}{H}$ | $\arccos \frac{O}{H}$ |
| O & θ | $\frac{O}{\tan \theta}$ | | $\frac{O}{\sin \theta}$ | | $90^\circ - \theta$ |
| O & ϕ | $O \tan \phi$ | | $\frac{O}{\cos \phi}$ | $90^\circ - \phi$ | |
| H & θ | $H \cos \theta$ | $H \sin \theta$ | | | $90^\circ - \theta$ |
| H & ϕ | $H \sin \phi$ | $H \cos \phi$ | | $90^\circ - \phi$ | |

Metric Relationships



The above chart shows the relation between the American and the metric systems of notation.

This chart also serves to quickly locate the decimal point in the conversion from one metric expression to another.

Example: Convert 5.0 milliwatts to watts. Place the finger on milli and count the number of steps from there to units (since the

term watt is a basic unit). The number of steps so counted is three, and the direction was to the left. Therefore, 5.0 milliwatts is the equivalent of .005 watts.

Example: Convert 0.00035 microfarads to micromicrofarads. Here the number of steps counted will be six to the right. Therefore 0.00035 microfarads is the equivalent of 350 micromicrofarads.

Metric Conversion Table

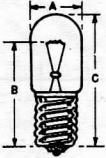
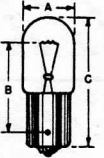
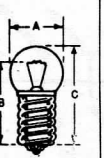
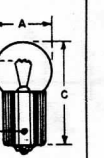
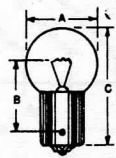
| ORIGINAL VALUE | DESIRED VALUE | | | | | | | |
|-------------------|---------------|------|-------|------|-------|-------|-------|------------|
| | Mega | Kilo | Units | Deci | Centi | Milli | Micro | Micromicro |
| Mega | | 3→ | 6→ | 7→ | 8→ | 9→ | 12→ | 18→ |
| Kilo | ← 3 | | 3→ | 4→ | 5→ | 6→ | 9→ | 15→ |
| Units | ← 6 | ← 3 | | 1→ | 2→ | 3→ | 6→ | 12→ |
| Deci | ← 7 | ← 4 | ← 1 | | 1→ | 2→ | 5→ | 11→ |
| Centi | ← 8 | ← 5 | ← 2 | ← 1 | | 1→ | 4→ | 10→ |
| Milli | ← 9 | ← 6 | ← 3 | ← 2 | ← 1 | | 3→ | 9→ |
| Micro | ← 12 | ← 9 | ← 6 | ← 5 | ← 4 | ← 3 | | 6→ |
| Micromicro | ← 18 | ← 15 | ← 12 | ← 11 | ← 10 | ← 9 | ← 6 | |

The above metric conversion table provides a fast and automatic means of conversion from one metric notation to another. The notation "Unit" represents the basic units of measurement, such as amperes, volts, ohms, watts, cycles, meters, grams, etc. To use the table, first locate the original or given value in the left-hand column. Now follow this line horizontally to the vertical column headed by the prefix of the desired value. The figure and arrow at this point indicates number of places and direction decimal point is to be moved.

Example: Convert 0.15 ampere to milli-amperes. Starting at the "Units" box in the left-hand column (since ampere is a basic unit of measurement), move horizontally to the column headed by the prefix "Milli", and read 3→. Thus 0.15 ampere is the equivalent of 150 milliamperes.

Example: Convert 50,000 kilocycles to megacycles. Read in the box horizontal to "Kilo" and under "Mega", the notation ←3, which means a shift of the decimal three places to the left. Thus 50,000 kilocycles is the equivalent of 50 megacycles.

Pilot Lamp Data

| Maximum Size See Chart below for dimensions |  |  |  |  |  | |
|---|---|---|---|---|---|------------------------|
| A | $1\frac{3}{32}"$ | $1\frac{3}{32}"$ | $\frac{7}{16}"$ | $\frac{7}{16}"$ | $\frac{7}{16}"$ | $\frac{7}{16}"$ |
| B | $1\frac{1}{16}"$ | $\frac{3}{4}"$ | $\frac{23}{32}"$ | $\frac{1}{2}"$ | $\frac{1}{2}"$ | $\frac{3}{4}"$ |
| C | $1\frac{3}{16}"$ | $1\frac{3}{16}"$ | $1\frac{1}{16}"$ | $1\frac{1}{16}"$ | $1\frac{1}{16}"$ | $1\frac{3}{16}"$ |
| Bulb No. | T-3 $\frac{1}{4}$ | T-3 $\frac{1}{4}$ | G-3 $\frac{1}{2}$ | G-3 $\frac{1}{2}$ | G-4 $\frac{1}{2}$ | G-5 |
| Base | Screw (Miniature) | Bayonet (Miniature) | Screw (Miniature) | Bayonet (Miniature) | Bayonet (Miniature) | Bayonet (Miniature) |
| Bulb Type | Tubular | Tubular | Small Round | Small Round | Large Round | Large Round |
| Lamp Numbers | 40 41 42 46 48 | 43 44 45 47 49 1490 | 50 | 51 | 55 | 1458 |

| Lamp No. | Bead Color | Base (Miniature) | Bulb Type | RATING | | Used for |
|-----------------|---------------|---------------------|-------------------|--------|-------|----------------------------------|
| | | | | Volts | Amps. | |
| 40 | Brown | Screw | T-3 $\frac{1}{4}$ | 6-8 | 0.15 | Dials |
| 41 | White | Screw | T-3 $\frac{1}{4}$ | 2.5 | 0.5 | Dials |
| 42 | Green | Screw | T-3 $\frac{1}{4}$ | 3.2 | † | Dials |
| 43 | White | Bayonet | T-3 $\frac{1}{4}$ | 2.5 | 0.5 | Dials and Tuning Meters |
| 44 | Blue | Bayonet | T-3 $\frac{1}{4}$ | 6-8 | 0.25 | Dials and Tuning Meters |
| 45 | * | Bayonet | T-3 $\frac{1}{4}$ | 3.2 | † | Dials |
| 46 [^] | Blue | Screw | T-3 $\frac{1}{4}$ | 6-8 | 0.25 | Dials and Tuning Meters |
| 47 | Brown | Bayonet | T-3 $\frac{1}{4}$ | 6-9 | 0.15 | Dials |
| 48 | Pink | Screw | T-3 $\frac{1}{4}$ | 2.0 | 0.06 | Battery Set Dials |
| 49 | Pink | Bayonet | T-3 $\frac{1}{4}$ | 2.0 | 0.06 | Battery Set Dials |
| 50 | White | Screw | G-3 $\frac{1}{2}$ | 6-8 | 0.2 | Auto-Radio Dials; Flashlights |
| 51 [^] | White | Bayonet | G-3 $\frac{1}{2}$ | 6-8 | 0.2 | Auto-Radio Dials; Panel Boards |
| 55 | White | Bayonet | G-4 $\frac{1}{2}$ | 6-8 | 0.4 | Auto-Radio Dials; Parking Lights |
| 1458 | | Bayonet | G-5 | 20.0 | 0.25 | Dials |
| 1490 | | Bayonet | T-3 $\frac{1}{4}$ | 3.2 | 0.15 | Dials |

* White in G.E. and Sylvania; Green in National Union Raytheon and Tung-Sol.

† 0.35 in G.E. and Sylvania; 0.5 in National Union Raytheon and Tung-Sol.

[^] Have frosted bulb.

Directly Interchangeable Tubes

| Tube Number | Replace with | Tube Number | Replace with | Tube Number | Replace with |
|-------------|--------------|-------------|--------------|-------------|--------------|
| 01A | 40 | 1LN5 | 1LC5 | | |
| 0A2 | 0B2 | 1N5 | { 1P5 | 5AX4 | { 5AZ4 |
| 0A3 | VR75 | | { 1D5 | | { 5U4 |
| 0A4 | 1267 | | { 1N5 | | { 5V4 |
| 0B3 | VR90 | 1P5 | { 1D5 | | { 5W4 |
| 0C3 | VR105 | 1Q5 | 1C5 | | { 5Y3 |
| 0D3 | VR150 | 1S6 | 1T6 | | { 5Z4 |
| 0Y4 | 0Y4G | | | | |
| | { CK1005 | 1T4 | { 1L4 | 5AX4 | { 5AX4 |
| 0Z4 | { 1003 | | { 1U4 | | { 5U4 |
| | { 0Z4A | 1T5 | { 1A5 | 5AZ4 | { 5V4 |
| | { 1B4 | 1T6 | { 1G4 | | { 5W4 |
| 1A4 | { 32 | | { 1S6 | | { 5Y3 |
| | { 34 | 1U4 | { 1L4 | | { 5Z4 |
| | { 1A4P | 1V | { 1T4 | | |
| | { 1A4T | | 6Z3 | 5AX4 | { 5AX4 |
| 1A5 | 1G4 | 1V5 | { 1AC5 | | { 5AZ4 |
| 1A7 | 1D7 | | { 1W5 | 5T4 | { 5U4 |
| 1AC5 | 1V5 | 1W5 | 1V5 | | { 5V4 |
| 1AD5 | 1W5 | 2A3 | 45 | | { 5W4 |
| | { 1A4 | 2A7 | 2A7S | | { 5Y3 |
| 1B4 | { 32 | 2B7S | 2B7 | | { 5Z4 |
| | { 34 | | | | |
| 1B8 | 1D8 | 2C52 | { 12SN7 | 5U4 | { 5AX4 |
| 1C5 | 1Q5 | | { 12SX7 | | { 5AZ4 |
| 1C8 | 1E8 | 2E5 | 2G5 | | { 5T4 |
| 1D5 | 1E5 | 2E30 | 5812 | | { 5V4 |
| 1D8 | 1B8 | 2E31 | 2E32 | | { 5W4 |
| 1E4 | 1G4 | 2E32 | 2E31 | | { 5Z4 |
| 1E5 | 1D5 | 2E35 | 2E36 | 5V4 | { 5AX4 |
| 1E8 | 1C8 | 2E36 | 2E35 | | { 5AZ4 |
| | { 1E4 | 2E41 | 2E42 | | { 5T4 |
| 1G4 | { 1H4 | 2E42 | 2E41 | | { 5U4 |
| 1G5 | 1J5 | 2G5 | 2E5 | | { 5W4 |
| | { 1G4 | 2G21 | 2G22 | | |
| 1H4 | { 1E4 | 2G22 | 2G21 | 5W4 | { 5AX4 |
| 1J5 | 1G5 | | { 3C5 | | { 5AZ4 |
| | { 1T4 | 3B5 | { 3Q5 | | { 5T4 |
| 1L4 | { 1U4 | 3B7 | 1291 | | { 5U4 |
| 1LA4 | 1LB4 | | | | { 5V4 |
| 1LA6 | 1LC6 | 3C5 | { 3B5 | | { 5Z4 |
| 1LB4 | 1LA4 | | { 3Q5 | | |
| | { 1LG5 | 3LE4 | 3LF4 | 5X3 | { 5Z3 |
| 1LC5 | { 1LN5 | 3Q4 | 3S4 | | { 80 |
| | { 1LA6 | 3Q5 | { 3B5 | | { 83 |
| 1LC6 | 1LA6 | | { 3C5 | | |
| 1LG5 | 1LC5 | 3S4 | 3Q4 | 5X4 | 5Y4 |

Directly Interchangeable Tubes—(Continued)

| Tube Number | Replace with | Tube Number | Replace with | Tube Number | Replace with |
|-------------|--------------|-------------|--------------|-------------|--------------|
| 5Y3 | 5AX4 | 6AJ5 | 6AK5 | 6C6 | 6D6 |
| | 5AZ4 | 6AJ7 | 6AB7 | | 77 |
| | 5T4 | | 6AC7 | 6D6 | 6C6 |
| | 5U4 | 6AK5 | 6AJ5 | | 77 |
| | 5V4 | 6AK7 | 6AG7 | 6D7 | 6E7 |
| 5Y4 | 5W4 | 6AL5 | 5726 | | 6T5 |
| | 5Z4 | | 6AV6 | 6E5 | 6U5 |
| | 5X4 | 6AT6 | 6BF6 | | 6D7 |
| 5Z3 | 5X3 | | 6BK6 | 6E7 | 6L4 |
| | 80 | | 6BT6 | 6F4 | 6L4 |
| | 83 | | 6BU6 | 6F7 | 6F7S |
| 5Z4 | 5AX4 | 6AU6 | 6AG5 | 6G5 | 6E5 |
| | 5AZ4 | | 6BA6 | | 6T5 |
| | 5T4 | | 6BD6 | 6H5 | 6U5 |
| | 5U4 | | 6AU5 | | 6U5 |
| | 5V4 | 6AV5 | 6BD5 | 6D5 | 6AD5 |
| 6A4 | 5W4 | 6AV6 | 6AT6 | | 6AE5 |
| | 5Y3 | 6AX4 | 6U4 | | 6AF5 |
| 6A8 | 52 | | 6W4 | | 6C5 |
| | 6J8 | 6B5 | 42 | 6J7 | 1233, 6K7 |
| 6AB7 | 6AC7 | 6B6 | 6Q7 | | 6U7 |
| | 6AJ7 | 6BA6 | 6AU6 | 6J8 | 6A8 |
| 6AC5G | 6AC5GT | | 6BD6 | | 6K8 |
| | 6AB7 | | 6AG5 | 6K4 | 6AD4 |
| | 6AJ7 | | 6BC5 | | 6J7 |
| 6AD4 | 6K4 | | 6CB6 | 6K7 | 6U7 |
| | 6AE5 | | 6AG5 | | 6AB |
| 6AD5 | 6AF5 | 6BC5 | 6AU6 | 6K8 | 6J8 |
| | 6C5 | | 6CB6 | | 6F4 |
| | 6J5 | | 6BE6 | 6L4 | 1614 |
| 6AD6 | 6AF6 | 6BF6 | 5915 | | 1612 |
| | 6AD5 | 6BG7 | 6BF7 | 6L6 | 6AD5 |
| 6AE5 | 6AF5 | 6BH6 | 6BJ6 | | 6AE5 |
| | 6C5 | 6BJ6 | 6BH6 | 6P5 | 6AF5 |
| | 6J5 | | 6AT6 | | 6C5 |
| 6AF5 | 6C5 | 6BK6 | 6AV6 | 6Q7 | 6J5 |
| | 6D5 | | 6BF6 | | 6B6, 6R7 |
| | 6AD5 | | 6BT6 | 6R7 | 6Q7 |
| | 6AE5 | | 6BU6 | | 6V7 |
| 6AF6 | 6AD6 | 6BT6 | 6BK6 | 6SA7 | 6SB7Y |
| | 6BC5 | 6BU6 | 6BF6 | 6S7 | 6W7 |
| 6AG5 | 6BA6 | 6C4 | 9002 | 6SB7Y | 6SA7 |
| | 6BD6 | 6C5 | 6AD5 | | 6SE7 |
| | 6CB6 | | 6AE5 | 6SD7 | 6SJ7 |
| | 6AU6 | | 6AF5 | | 6SK7 |
| | | | 6D5 | | 5693 |

Directly Interchangeable Tubes—(Continued)

| Tube Number | Replace with | Tube Number | Replace with | Tube Number | Replace with |
|-------------|--------------------------------|-------------|------------------------------------|-------------|------------------------------------|
| 6SE7 | { 6SD7 6SJ7 6SK7 5613 | 7AH7 | 7AG7 | 12AY7 | 12AX7 |
| 6SF7 | 6SV7 | 7AJ7 | 7H7 | 12AZ7 | 12AV7 |
| 6SH7 | { 6SG7 6SJ7 6SK7 | 7B4 | 7A4 | 12B7 | 14A7 |
| 6SJ7 | 6SK7, 5693 | 7B6 | 7E6 | 12BA6 | { 12AU6 12BD6 |
| 6SK7 | { 6SG7 6SH7 6SJ7 | 7B7 | { 7C7 7AH7 | 12BD6 | { 12AU6 12BA6 |
| 6SL7 | { 6SU7 5691, 5692 | 7B8 | { 7J7 7S7 | 12BF6 | 12BU6 |
| 6SN7 | { 5692 5691 | 7C7 | 7B7 | 12BK6 | { 12AT6 12AV6 12BT6 12BU6 |
| 6SQ7 | 6SR7 | 7E5 | 1201 | 12BT6 | { 12AT6 12AV6 12BK6 12BU6 |
| 6SR7 | 6SQ7 | 7E6 | 7B6 | 12BU6 | 12BF6 |
| 6ST7 | 6SZ7 | 7E7 | 7R7 | 12J7 | 12K7 |
| 6SU7 | 6SL7 | 7F7 | 7AF7 | 12K7 | 12J7 |
| 6SV7 | 6SF7 | 7G7 | 7V7 | 12K8 | 12A8 |
| 6SZ7 | 6ST7 | 7H7 | { 7A7 7L7 | 12L8 | 1644 |
| 6T5 | { 6E5 6U5 | 7J7 | 7B8 | 12SA7 | 12SY7 |
| 6U4 | { 6W4 6AX5 | 7L7 | { 7A7 7H7 | 12SC7 | 1634 |
| 6U5 | { 6E5 6T5 | 7R7 | 7E7 | 12SG7 | { 12SH7 12SJ7 12SK7 |
| 6U7 | 6K7 | 7S7 | { 7B8 7J7 | 12SH7 | { 12SG7 12SJ7 12SK7 |
| 6V7 | 6R7 | 7T7 | 7A7, 7H7, 7V7 | 12SJ7 | { 12SG7 12SH7 12SK7 |
| 6W4 | { 6U4 6AX4 | 7V7 | 7T7, 7A7, 7H7 | 12SK7 | { 12SG7 12SH7 12SJ7 |
| 6W7 | 6S7 | 7Z4 | 7X6 | 12SN7 | 12SX7 |
| 6X8 | 6U8 | 10 | 10Y | 12SQ7 | 12SR7 |
| 6Z3 | 1V | 10Y | 10 | 12SR7 | 12SQ7 |
| 6Z5 | 6Y5 | 12A | 71A | 12SW7 | 12SR7 |
| 7A4 | 7B4 | 12A8 | 12K8 | 12SX7 | 12SN7 |
| 7A7 | { 7H7 7L7 | 12AT6 | { 12AV6 12BK6 | 12SY7 | 12SA7 |
| 7AB7 | 1204 | 12AT7 | 12AU7 | 14A7 | 12B7 |
| 7AF7 | 7F7 | 12AU6 | { 12BA6 12BD6 | | |
| 7AG7 | 7AH7 | 12AU7 | 12AT7 | | |
| | | 12AV6 | { 12AT6 12BK6 12BT6 12BU6 | | |
| | | 12AV7 | 12AZ7 | | |
| | | 12AX7 | 12AY7 | | |

Directly Interchangeable Tubes—(Continued)

| Tube Number | Replace with | Tube Number | Replace with | Tube Number | Replace with |
|-------------|--------------------------------|-------------|---------------|-------------|--------------------------------|
| 14AF7 | 14F7 | 40 | 01A | 1232 | 7G7 |
| 14B6 | 14E6 | 41 | 42 | 1267 | 0A4 |
| 14B8 | { 14J7 14S7 | 42 | 6B5 | 1273 | 7A7 |
| 14C7 | { 12B7 1284 | 45 | 2A3 | 1274 | 6Y5 |
| 14E6 | 14B6 | 50 | 10 | 1275 | { 5X3 80 83 |
| 14E7 | 14R7 | 50A6 | 50Z6 | 1280 | 14H7 |
| 14F7 | 14AF7 | 50C6 | 50L6 | 1284 | 12B7 |
| 14H7 | { 12B7 14A7 | 50Y7 | 50Z7 | 1291 | 3B7 |
| 14J7 | { 14B8 14S7 | 50Z6 | 50AX6 | 1294 | 1R4 |
| 14R7 | 14E7 | 50Z7 | 50Y7 | 1299 | 3D6 |
| 14S7 | { 14J7 14B8 | 53 | 5608-A | 1612 | 6L7 |
| 14W7 | { 12B7 14A7 | 55 | 2A6 | 1614 | 6L6 |
| 19C8 | 19T8 | 56 | 27 | 1620 | 6J7 |
| 19T8 | 19C8 | 57 | 58 | 1634 | 12SC7 |
| 25A6 | { 25B6 25C6 25L6 5824 | 76 | 37 | 1644 | 12L8 |
| 25A7 | 32L7 | 77 | 6C6 | 5517 | CK1003 |
| 25B5 | 43 | 78 | 6D6 | 5590 | { 9001, 5591 9003 |
| 25S | 1B5 | 80 | { 83 5Z3 | 5591 | 5590 |
| 25Y5 | 25Z5 | 81 | 50 | 5608-A | 53 |
| 26BK6 | 26C6 | 82 | { 2A3 45 | 5654 | { 6AJ5 6AK5 |
| 26C6 | 26BK6 | 83 | 5Z3, 80 | 5672 | 5678 |
| 27 | 56 | 85 | 75 | 5678 | 5672 |
| 32 | { 1A4 1B4 | 117L7 | 117M7 | 5691 | { 6SN7 5692 |
| 32L7 | 25A7 | 117N7 | 117P7 | 5692 | { 5691 6SN7 |
| 34 | { 1A4 1B4 | 950 | 1F4 | 5693 | 6SJ7 |
| 36 | 39 | 954 | 956 | 5725 | { 6AJ5 6AK5 |
| 37 | 76 | 955 | 5731 | 5731 | 9J5 |
| 39 | 36 | 956 | 954 | 5824 | { 25A6 25B6 25C6 25L6 |
| | | CK1005 | { 0Y4 0Z4A | 5915 | 6BE6 |
| | | CK1013 | 5517 | | |
| | | 1201 | 7E5 | | |
| | | 1203 | 7C4 | | |
| | | 1204 | 7AB7 | | |
| | | 1206 | 768 | | |
| | | 1221 | 6C6 | | |
| | | 1223 | 6J7 | | |
| | | 1229 | 1A4 | | |
| | | 1230 | 30 | | |
| | | 1231 | 7V7 | | |

Directly Interchangeable TV Picture Tubes

| Tube Number | Replace with | Tube Number | Replace with | Tube Number | Replace with |
|-------------|--------------|-------------|--------------|-------------|--------------|
| 7NP4 | 7WP4* | 12VP4 | 12VP4A | 16JP4 | 16JP4A |
| 7WP4 | 7NP4 | 14BP4 | 14BP4A | 16JP4 | 16HP4 |
| 8AP4 | 8AP4A | 14BP4 | 14CP4 | 16JP4A | 16HP4A |
| 8AP4A | 8AP4 | 14BP4A | 14EP4 | 16KP4 | 16KP4A |
| 10BP4 | 10BP4A | 14CP4 | 14BP4 | 16KP4 | 16RP4 |
| 10BP4 | 10FP4 | | 14BP4A | 16KP4A | 16TP4 |
| 10BP4A | 10FP4A | | 14EP4 | 16LP4 | 16LP4A |
| 10EP4 | 10CP4 | 14EP4 | 14BP4 | 16LP4 | 16ZP4 |
| 10FP4 | 10FP4A | | 14BP4A | 16LP4A | |
| 10MP4 | 10MP4A | | 14CP4 | | |
| 10MP4A | 10MP4 | 14FP4 | 14BP4• | 16MP4 | 16MP4A |
| 12KP4 | 12KP4A | | 14BP4A• | 16MP4 | 16HP4 |
| 12LP4 | 12LP4A | | 14CP4• | 16MP4A | 16HP4A |
| 12LP4 | 12KP4* | 15CP4 | 14EP4• | 16QP4 | 16XP4 |
| 12LP4A | 12KP4A* | 16AP4 | | 16RP4 | 16KP4 |
| | 12VP4 | 16AP4A | 16AP4A | | 16KP4A |
| | 12VP4A | 16CP4 | 16AP4 | | 16TP4 |
| | 12TP4 | 16CP4 | 15CP4 | 16SP4 | 16SP4A |
| 12QP4 | 12QP4A | 16DP4 | 16DP4A | 16SP4A | 16SP4 |
| 12QP4 | 12JP4* | 16DP4 | 16HP4• | 16SP4 | 16WP4A |
| 12QP4A | 12RP4 | 16DP4A | 16HP4A• | 16SP4A | |
| 12RP4 | 12JP4* | | 16JP4• | 16UP4 | 16KP4• |
| | 12QP4 | | 16JP4A• | | 16KP4A• |
| | 12QP4A | | 16MP4• | | 16RP4• |
| 12TP4 | 12KP4** | 16EP4 | 16MP4A• | | 16TP4• |
| | 12KP4A** | | | 16VP4 | 16YP4• |
| | 12RP4* | 16GP4 | 16EP4A | 16WP4 | 16SP4• |
| | 12VP4• | | 16EP4B | | 16SP4A• |
| | 12VP4A• | | | | 16WP4A• |
| 12UP4 | 12UP4A | 16HP4 | 16HP4A | 16WP4A | 16SP4 |
| | | 16HP4A | 16JP4 | | 16SP4A |
| | | | 16JP4A | | |

•Connect external connector to chassis.

*Remove ion trap.

Directly Interchangeable TV Picture Tubes (Continued)

| Tube Number | Replace with | Tube Number | Replace with | Tube Number | Replace with |
|-------------|---|-------------|---------------------------------------|-------------|-----------------------------|
| 16XP4 | 16QP4 | 17QP4 | 17UP4 | 20GP4 | 20JP4 |
| 16ZP4 | 16LP4 16LP4A | 17RP4 | 17HP4 17HP4A 17KP4 | 20HP4 | 20HP4B |
| 17AP4 | 17BP4A 17BP4B 17BP4C 17JP4 | 17UP4 | 17QP4 | 20HP4 | 20HP4A● |
| 17BP4 | 17AP4● 17BP4A● 17BP4B● 17BP4C● 17JP4● | 17VP4 | 17LP4 17LP4A 17SP4 | 20HP4B | 20JP4● 20LP4● |
| 17BP4A | 17BP4B 17BP4C | 19AP4 | 19AP4A 19AP4B 19AP4C 19AP4D | 21EP4A | 21EP4B |
| 17BP4A | 17BP4B 17BP4C | 19DP4 | 19DP4A | 21FP4 | 21FP4A● 21KP4 21KP4A● |
| 17BP4A | 17AP4 | 19DP4A | 19DP4 | 21FP4A | 21KP4A |
| 17BP4B | 17JP4 | 19EP4 | 19JP4 | 21KP4 | 21KP4A● |
| 17BP4C | | 19FP4 | 19DP4● 19DP4A● | 21WP4 | 20CP4A 20DP4A |
| 17CP4 | 17CP4A | 19JP4 | 19EP4 | 21ZP4 | 21ZP4A● |
| 17CP4A | 17CP4 | 20CP4 | 20CP4A 20CP4C 20DP4 20DP4A● | 22AP4 | 22AP4A |
| 17FP4 | 17FP4A | 20CP4A | 20CP4● 20DP4A | 22AP4A | 22AP4 |
| 17FP4A | 17FP4 | 20CP4C | 20CP4 20CP4A● 20DP4 | 24AP4 | 24AP4A 24AP4B |
| 17HP4 | 17HP4A | 20CP4C | 20CP4 20CP4A● 20DP4 | 24AP4B | 24AP4 24AP4A |
| 17HP4A | 17HP4 | 20CP4C | 20CP4 20CP4A● 20DP4 | 27EP4 | 27GP4 27NP4 27RP4 |
| 17HP4 | 17KP4 | 20CP4C | 20CP4 20CP4A● 20DP4 | 27GP4 | 27EP4 27NP4● 27RP4● |
| 17HP4A | 17RP4 | 20DP4 | 20CP4 20CP4C 20CP4A● 20DP4A● | 27NP4 | 27EP4 27GP4 27RP4 |
| 17JP4 | 17AP4 17BP4A 17BP4B 17BP4C | 20FP4 | 20GP4● 20JP4 | 27RP4 | 27EP4 27GP4 27NP4 |
| 17LP4 | 17LP4A | | | | |
| 17LP4 | 17SP4 | | | | |
| 17LP4A | 17VP4 | | | | |

●Connect external connector to chassis.

Interchangeable Batteries

| Burgess | Eveready | Neda | Ray-O-Vac | RCA | Burgess | Eveready | Neda | Ray-O-Vac | RCA |
|---------|----------|------|-----------|--------|---------|----------|------|-----------|----------|
| 1 | 935-635 | 14 | 1LP | VS035 | B5 | 713 | 8 | P551 | VS129 |
| 10308* | W363F | 716 | 5930C | VS127 | B30 | 484 | 207 | P5303 | VS012 |
| 120 | 835 | | 110LP | | C5 | 717 | 9 | P751 | VS065 |
| 17GD60 | 759 | 413 | AB82 | VS022 | D3 | 726 | 19 | 423PX | VS072 |
| 2 | 950 | | 2LP | VS036 | F2BP | W352 | 701 | 392S | VS100 |
| 2F | W353 | 11 | 192PX | VS141 | F3 | 736 | 3 | P93A | VS067 |
| 2F4 | 718 | 1 | 698P | VS010 | F4A50 | W368 | 411 | AB327 | |
| 2F4L | 747 | 16 | 698PL | VS011 | F4H | 409 | 908 | 941 | VS040C |
| 2D | 720 | 18 | 122P | VS069 | F4PI | 744 | 6 | P694A | VS009 |
| 2FBP | W354 | 700 | 192S | VS101 | F6A60 | 753 | 401 | AB994 | VS019 |
| 2R | 950 | 13 | 2LP | VS036 | F6A60P | 757 | 406 | AB909 | VS058 |
| 2TXX40 | W370 | 412 | | | G3 | 746 | 7 | P83A | VS002 |
| 20F | 740 | 719 | P9203 | VS024 | G5A42 | W367 | 408 | AB-794 | VS038 |
| 20F2 | X125 | 720 | P9403 | VS025 | G6B60 | 752 | 400 | AB-995 | VS047 |
| 21R | 964 | 20 | 8R | VS236 | G6M60 | 754 | 402 | AB-878 | VS018 |
| 210 | 1050 | | 3LP | | K45 | 457 | 203 | NSW45 | VS082 |
| 21308* | W364F | 715 | 5830C | VS157 | M30 | 482 | 202 | P7830 | VS013 |
| 2156 | 766T | 702 | 2215C | VS137 | N | | 910 | 716 | VS073 |
| 220 | 850 | | 210LP | | N60 | 490 | 204 | 4390 | VS090 |
| 2308* | W365F | 723 | 5230C | VS126 | P45 | 477 | 211P | NW45 | VS218 |
| 2370ST | 761T | 712 | 423S | VS130 | P45M | | 211M | 946 | VS216-15 |
| 2370PI | 771 | 718 | P231W | VS030 | P60 | 479 | | | |
| 4F | 742 | 4 | 194P | VS004 | S461 | 1461 | 907 | 641 | VS039 |
| 4FH | 735 | 900 | 194S | VS106 | S6D60 | 776 | 415 | AB326 | VS119 |
| 4FL | | 12 | P94L | VS005 | T5 | W360 | 10 | 7CD5P | |
| 4F2H | W357 | 901 | 398C | VS138 | T5Z50 | 755 | 403 | AB775 | VS050 |
| 4F4H | 706 | 902 | 902 | VS103 | T6Z60 | 756 | 405 | AB601 | VS057W |
| 4F5H | 715 | 903 | 903 | VS139 | T6Z60P | 756P | 428 | | VS059 |
| 4F6H | 716 | 904 | 904 | VS140 | U10 | 411 | 208 | 510P | VS083 |
| 4GA42 | W366 | 407 | AB944 | VS053 | U15 | 412 | 215 | 215 | VS084 |
| 4SD60 | 758 | 414 | AB85 | VS021 | U15PF | 412 | | 915 | |
| 4TZ60 | 729 | 425 | AB333 | VS064 | U20 | 413 | 210 | 520P | VS085 |
| 4156 | 763 | 710 | 2415S | VS102 | U200 | 493 | 722 | 5200 | VS093 |
| 422 | 750 | 704 | 342 | VS134 | U30 | 415 | 213 | 530CUH | VS086 |
| 432 | 751 | 705 | 443 | VS142 | W20PI | | | 99917 | |
| 5156SC | 778 | 708 | 2515C | VS131 | W30PI | 733 | | N30P | |
| 5156PI | 768 | 721 | 2515P | VS031 | XX15 | 425P | | PN15 | |
| 5308 | W376 | 709 | 5530S | VS112 | XX22 | 433P | | PN22 | |
| 532 | 703 | 706 | 453 | VS133 | XX30 | 455 | 201 | 930 | VS055 |
| 5360 | 781 | 714 | 531R | VS028 | XX30PI | 455P | | PN30F | |
| 5540 | 773 | 713 | 755S | VS029 | XX45 | 467 | 200 | 4367 | VS016 |
| 6F | 743 | 5 | 196P | VS007 | XX50 | 437 | 212 | 4375 | VS217 |
| 6 Ign. | 6 Ign. | 905 | 6 Ign.-S | VS0065 | XX69 | W361 | | 103SN69 | |
| 6 Ind. | 6 Ind. | 911 | 6 RR | | Y10 | 504 | | 10P | |
| 6 Tel. | 6GL | 906 | 6 Tel.-C | VS042C | Y15 | 505 | | 515P | |
| 6TA60 | W369 | 410 | AB64 | VS054 | Y20 | 506 | | 20P | |
| 7 | 912 | 24 | 400 | | Y20S | 507 | | | |
| 8F | 741 | 17 | 198P | | Z | 915 | 15 | 7R | VS034 |
| 8R | 960P | 23 | 191P | VS070 | Z30 | 738 | 205 | 57R30P | VS015 |
| 9R | 1015E | | 41 | | Z30NX | W350 | 711 | 57R30S | VS114 |
| 920 | 815 | | 710LP | | Z4 | 724 | 2 | 67R4 | VS068 |
| A30 | W359 | 206 | P430 | VS014 | | | | | |

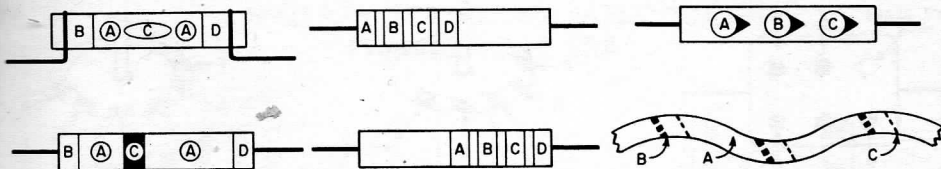
* Available with plug-in terminal also.

Interchangeable Batteries—(Continued)

| Eveready | Burgess | Neda | Ray-O-Vac | RCA | Eveready | Burgess | Neda | Ray-O-Vac | RCA |
|---------------|---------|------|-----------|--------|--------------|---------|------|-----------|--------|
| 6GL | 6 Tel. | 906 | 6 Tel.-C | VS042C | 716 | 4F6H | 904 | 904 | VS140 |
| 6 Ign. | 6 Ign. | 905 | 6 Ign.-S | VS006S | 717 | C5 | 9 | P751 | VS065 |
| 6 Ind. | 6 Ind. | 911 | 6RR | | 718 | 2F4 | 1 | 698P | VS010 |
| X-125 | 20F2 | 720 | P9403 | VS025 | 720 | 2D | 18 | 122P | VS069 |
| W-350 | Z30NX | 711 | 57R30S | VS114 | 724 | Z4 | 2 | 67R4 | VS068 |
| W-351 | Z30BP | | | | 726 | D3 | 19 | 423PX | VS072 |
| W-352 | F2BP | 701 | 392S | VS100 | 729 | 4TZ60 | 425 | AB333 | VS064 |
| W-354 | 2FBP | 700 | 192S | VS101 | 735 | 4FH | 900 | 194S | VS106 |
| W-355 | 2BBP | | | | 736 | F3 | 3 | P93A | VS067 |
| W-356 | 2F2H | | | VS136 | 738 | Z30 | 205 | 57R30P | VS015 |
| W-357 | 4F2H | 901 | 398C | VS138 | 740 | 20F | 719 | P9203 | VS024 |
| W-358 | W30BPX | | | | 741 | 8F | 17 | 198P | |
| W-362 | W5BP | | | | 742 | 4F | 4 | 194P | VS004 |
| W-363F | 10308SC | 716 | 5930C | VS127 | 743 | 6F | 5 | 196P | VS007 |
| W-363P | 10308PI | | | VS027 | 744 | F4PI | 6 | P694A | VS009 |
| W-364F | 21308SC | 715 | 5830C | VS157 | 746 | G3 | 7 | P83A | VS002 |
| W-364P | 21308PI | | | | 747 | 2F4L | 16 | 698PL | VS011 |
| W-365F | 2308SC | 723 | 5230C | VS126 | 750 | 422 | 704 | 342 | VS134 |
| W-365P | 2308PI | | | VS026 | 751 | 432 | 705 | 443 | VS142 |
| W-371 | 2Z2PI | | | | 752 | G6B60 | 400 | AB995 | VS047 |
| W-376 | 5308 | 709 | 5530S | VS112 | 753 | F6A60 | 401 | AB994 | VS019 |
| 409 | F4H | 908 | 941 | VS040C | 754 | G6M60 | 402 | AB878 | VS018 |
| 411 | U10 | 208 | 510P | VS083 | 755 | T5Z50 | 403 | AB775 | VS050 |
| 412 | U15 | | | | 756 | T6Z60 | 405 | AB601 | VS057W |
| | U15PF | 215 | 215, 915 | VS084 | 756-P | T6Z60P | 428 | | VS059 |
| 413 | U20 | 210 | 520P | VS085 | 757 | F6A60P | 406 | AB909 | VS058 |
| 415 | U30 | 213 | 530CUH | VS086 | 758 | 4SD60 | 414 | AB85 | VS021 |
| 437 | XX50 | 212 | 4375 | VS217 | 759 | 76D60 | 413 | AB82 | VS022 |
| 455 | XX30 | 201 | 930 | VS055 | 761T | 2370ST | 712 | 423S | VS130 |
| 457 | K45 | 203 | NSW45 | VS082 | 762S | 5308 | 709 | 5530S | VS119 |
| 467 | XX45 | 200 | 4367 | VS016 | 763 | 4156 | 710 | 2415S | VS102 |
| 477 | P45 | 211P | NW45 | VS218 | 766T | 2156 | 702 | 2215C | VS137 |
| 479 | P60 | | | | 768 | 5156PI | 721 | 2515P | VS031 |
| 482 | M30 | 202 | P7830 | VS013 | 771 | 2370PI | 718 | P231W | VS030 |
| 484 | B30 | 207 | P5303 | VS012 | 773 | 5540 | 713 | 755S | VS029 |
| 490 | N60 | 204 | 4390 | VS090 | 776 | 56D60 | 415 | AB326 | VS119 |
| 493 | U200 | 722 | 5200 | VS093 | 778 | 5156SC | 708 | 2515C | VS131 |
| 504 | Y10 | | 10P | | 781 | 5360 | 714 | 531R | VS028 |
| 505 | Y15 | | 515P | | 912 | 7 | 24 | 400 | |
| 506 | Y20 | | 20P | | 915 | Z | 15 | 7R | VS034 |
| 507 | Y20S | | | | 935 | 1 | 14 | 1LP | VS035 |
| 635 | 1 | 14 | 1LP | VS035 | 950 | 2, 2R | 13 | 2LP | VS036 |
| 703 | 532 | 706 | 453 | VS133 | 960-P | 8R | 23 | 191P | VS070 |
| 706 | 4F4H | 902 | 902 | VS103 | 964 | 21R | 20 | 8R | VS236 |
| 713 | B5 | 8 | P551 | VS129 | 1461 | S461 | 907 | 641 | VS039 |
| 715 | 4F5H | 903 | 903 | VS139 | | | | | |

Resistor Color Code

RETMA STANDARD REC-116 MILITARY STANDARD MIL-R-11A



| Color | 1st Digit A | 2nd Digit B | Multiplier C | Tolerance D |
|----------|----------------|----------------|-----------------|----------------|
| Black | 0 | 0 | 1 | — |
| Brown | 1 | 1 | 10 | — |
| Red | 2 | 2 | 100 | — |
| Orange | 3 | 3 | 1,000 | — |
| Yellow | 4 | 4 | 10,000 | — |
| Green | 5 | 5 | 100,000 | — |
| Blue | 6 | 6 | 1,000,000 | — |
| Violet | 7 | 7 | 10,000,000 | — |
| Gray | 8 | 8 | 100,000,000 | — |
| White | 9 | 9 | — | — |
| Gold | — | — | 0.1 | ± 5% |
| Silver | — | — | 0.01* | ± 10% |
| No Color | — | — | *RETMA ONLY. — | ± 20% |

INSULATION CODING

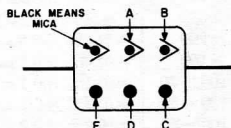
RETMA: Insulated resistors with axial leads are designated by a background of any color except black. The usual color is natural tan. Noninsulated resistors with axial leads are designated by a black background color.

MILITARY (MIL): Same as RETMA with the addition of: Noninsulated resistors with radial leads designated by a black background color or by a background the same color as the first significant figure of the resistance value.

Mica Capacitor Color Code

MILITARY STANDARD

MIL-C-5A



| Color | Digits of Capacitance (μf) | | Multiplier C | Tolerance % D | Characteristic. See table below E |
|--------|---|---|-----------------|---------------------|---|
| | A | B | | | |
| Black | 0 | 0 | 1 | ± 20 | — |
| Brown | 1 | 1 | 10 | — | B |
| Red | 2 | 2 | 100 | ± 2 | C |
| Orange | 3 | 3 | 1,000 | — | D |
| Yellow | 4 | 4 | — | — | E |
| Green | 5 | 5 | — | — | F |
| Blue | 6 | 6 | — | — | — |
| Violet | 7 | 7 | — | — | — |
| Gray | 8 | 8 | — | — | — |
| White | 9 | 9 | — | — | — |
| Gold | — | — | 0.1 | ± 5 | — |
| Silver | — | — | 0.01 | ± 10 | — |

DESCRIPTION OF CHARACTERISTIC

| Charac- teristic | Temperature Coefficient (parts per million per °C) | Maximum Capacitance Drift | Minimum Insulation Resistance (megohms) |
|---------------------|---|---------------------------------|--|
| B | Not specified | Not specified | 7500 |
| C | ±200 | ±0.5% | 7500 |
| D | ±100 | ±0.3% | 7500 |
| E | +100 -20 | ±(0.1% +0.1 μf) | 7500 |
| F | +70 | ±(0.05% +0.1 μf) | 7500 |

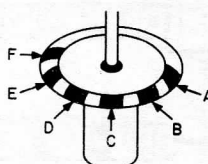
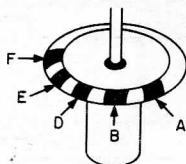
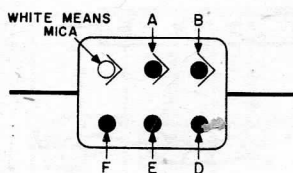
VOLTAGE RATING

(Indicated by dimensions rather than color coding)

| Maximum Inches | | | Style CM | Capacitance (μf) | Rating (v d-c) |
|----------------|---------|---------|-------------|----------------------------------|-------------------|
| Long | Wide | Thick | | | |
| $35/64$ | $5/16$ | $7/32$ | 15 | 5-510 | 300 |
| $51/64$ | $15/32$ | $7/32$ | 20 | 5-510 560-1000 | 500 300 |
| $17/64$ | $15/32$ | $7/32$ | 25 | 51-1000 | 500 |
| $53/64$ | $53/64$ | $9/32$ | 30 | 560-3300 | 500 |
| $53/64$ | $53/64$ | $11/32$ | 35 | 3600-6200 6800-10,000 | 500 300 |
| $11/32$ | $41/64$ | $11/32$ | 40 | 3300-8200 9100-10,000 | 500 300 |

Mica Capacitor Color Code

RETMA STANDARD REC-115A



| Color | Digits of Capacitance (μf) | | | Multiplier D | Tolerance % E | Characteristic— See table below F |
|--------|---|---|---|-----------------|------------------|---|
| | A | B | C | | | |
| Black | 0 | 0 | 0 | 1 | ± 20 | A |
| Brown | 1 | 1 | 1 | 10 | ± 1 | B |
| Red | 2 | 2 | 2 | 100 | ± 2 | C |
| Orange | 3 | 3 | 3 | 1,000 | ± 3 | D |
| Yellow | 4 | 4 | 4 | 10,000 | ± 4 | E |
| Green | 5 | 5 | 5 | — | ± 5 | — |
| Blue | 6 | 6 | 6 | — | — | — |
| Violet | 7 | 7 | 7 | — | — | — |
| Gray | 8 | 8 | 8 | — | — | I |
| White | 9 | 9 | 9 | — | — | J |
| Gold | — | — | — | 0.1 | — | — |
| Silver | — | — | — | 0.01 | ± 10 | — |

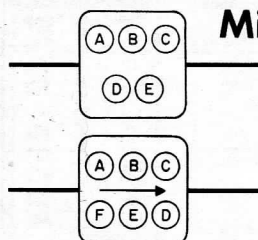
DESCRIPTION OF CHARACTERISTIC

| Characteristic | Temperature Coefficient (parts per million per $^{\circ}\text{C}$) | Maximum Capacitance Drift | Minimum Insulation Resistance (megohms) |
|----------------|---|---------------------------------|---|
| A | ± 1000 | $\pm (5\% + 1 \mu\text{f})$ | 3000 |
| B | ± 500 | $\pm (3\% + 1 \mu\text{f})$ | 6000 |
| C | ± 200 | $\pm (0.5\% + 0.5 \mu\text{f})$ | 6000 |
| D | ± 100 | $\pm (0.3\% + 0.1 \mu\text{f})$ | 6000 |
| E | +100 -20 | $\pm (0.1\% + 0.1 \mu\text{f})$ | 6000 |
| I | +150 -50 | $\pm (0.3\% + 0.2 \mu\text{f})$ | 6000 |
| J | +100 -50 | $\pm (0.2\% + 0.2 \mu\text{f})$ | 6000 |

VOLTAGE RATING

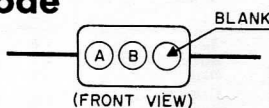
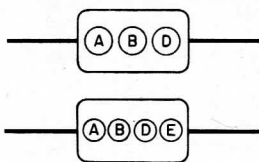
(Indicated by dimensions rather than color coding)

| Maximum Inches | | | Style | Capacitance (μf) | Rating (v d-c) |
|-----------------|-----------------|-----------------|-------|------------------------------------|--------------------|
| Long | Wide | Thick | | | |
| $5\frac{1}{64}$ | $1\frac{5}{32}$ | $\frac{7}{32}$ | 20 | 5-510 560-1000 | 500 300 |
| $1\frac{7}{64}$ | $1\frac{5}{32}$ | $\frac{7}{32}$ | 25 | 5-1000 1100-1500 | 500 300 |
| $5\frac{3}{64}$ | $5\frac{3}{64}$ | $\frac{9}{32}$ | 30 | 470-6200 Over 6200 | 500 300 |
| $5\frac{3}{64}$ | $5\frac{3}{64}$ | $\frac{9}{32}$ | 35 | 3300-6200 Over 6200 | 500 300 |
| $1\frac{1}{32}$ | $4\frac{1}{64}$ | $1\frac{1}{32}$ | 40 | 100-2400 2700-7500 Over 7500 | 1000 500 300 |

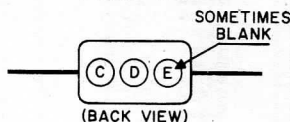


Mica Capacitor Color Code

Obsolete Style



(FRONT VIEW)



(BACK VIEW)

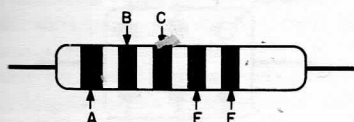
| Dot Color | Digits of Capacitance (μf) | | | Multiplier D | Tolerance % E | Voltage Rating (v d-c) F |
|-----------|---|---|---|-----------------|------------------|--------------------------------|
| | A | B | C | | | |
| Black | 0 | 0 | 0 | 1 | ± 20 | — |
| Brown | 1 | 1 | 1 | 10 | ± 1 | 100 |
| Red | 2 | 2 | 2 | 100 | ± 2 | 200 |
| Orange | 3 | 3 | 3 | 1,000 | ± 3 | 300 |
| Yellow | 4 | 4 | 4 | 10,000 | ± 4 | 400 |
| Green | 5 | 5 | 5 | 100,000 | ± 5 | 500 |
| Blue | 6 | 6 | 6 | 1,000,000 | ± 6 | 600 |
| Violet | 7 | 7 | 7 | 10,000,000 | ± 7 | 700 |
| Gray | 8 | 8 | 8 | 100,000,000 | ± 8 | 800 |
| White | 9 | 9 | 9 | 1,000,000,000 | ± 9 | 900 |
| Gold | — | — | — | 0.1 | ± 5 | 1,000 |
| Silver | — | — | — | 0.01 | ± 10 | 2,000 |
| No Color | — | — | — | — | ± 20 | 500 |

Ceramic Capacitor Color Code

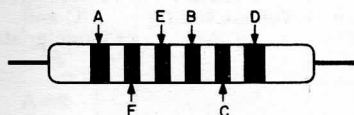
RETMA STANDARD REC-107A

MILITARY STANDARD JAN-C-20A

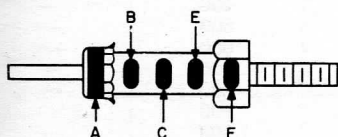
Proposed Mil-C-20A



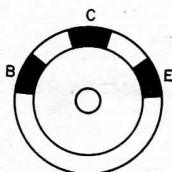
Tubular Capacitors
(Voltage rating is always 500 v.)



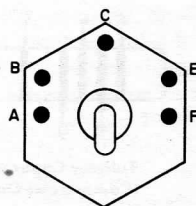
Tubular Capacitors
(Old RMA)



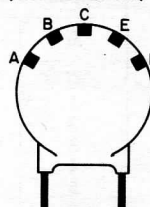
Stand-Off Capacitors
(RETMA ONLY)



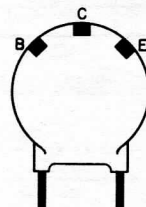
3-Dot Button Capacitors
RETMA ONLY



Feed Through Capacitors
(RETMA ONLY)



5-Dot Disc Capacitors
(RETMA ONLY)
(Voltage rating is always 500 v.)



3-Dot Disc Capacitors
(RETMA ONLY)
(Voltage rating is always 500 v., tolerance is always -0.)

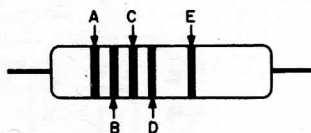
| Color | Digits of Capacitance ($\mu\mu\text{f}$) | | | Multiplier E | Tolerance F | | Temp. Coef. A (Parts per million per °C.) | |
|--------|--|---|---|--------------|--|------------------------------|--|----------|
| | B | C | D | | 10 $\mu\mu\text{f}$ or less ($\mu\mu\text{f}$) | Over 10 $\mu\mu\text{f}$ (%) | RETMA | MILITARY |
| Black | 0 | 0 | 0 | 1 | ± 2.0 | $\pm 20^*$ | 0 | 0 |
| Brown | 1 | 1 | 1 | 10 | $\pm 0.1^*$ | ± 1 | — 33 | — 30 |
| Red | 2 | 2 | 2 | 100 | — | ± 2 | — 75 | — 80 |
| Orange | 3 | 3 | 3 | 1,000 | — | $\pm 2.5^*$ | — 150 | — 150 |
| Yellow | 4 | 4 | 4 | 10,000* | — | — | — 220 | — 220 |
| Green | 5 | 5 | 5 | — | ± 0.5 | ± 5 | — 330 | — 330 |
| Blue | 6 | 6 | 6 | — | — | — | — 470 | — 470 |
| Violet | 7 | 7 | 7 | — | — | — | — 750 | — 750 |
| Gray | 8 | 8 | 8 | 0.01 | ± 0.25 | — | +150 to —1500 | + 30 |
| White | 9 | 9 | 9 | 0.1 | ± 1.0 | ± 10 | +100 to —750 | +330* |
| Gold | — | — | — | — | — | — | — | +100 |

*RETMA only

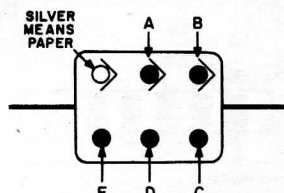
Paper Capacitor Color Code

MILITARY STANDARD MIL-C-91A

(Commercial codes are same except as noted)



Tubular Capacitors
(Commercial Only)



Rectangular Capacitors

| Color | Digits of Capacitance (μf) | | Multiplier C | Tolerance % D | Tubular Voltage Rating (v d-c) E | Temp. Rating $^{\circ}\text{C}$ and Characteristic F |
|--------|---|---|-----------------|---------------------|---|---|
| | A | B | | | | |
| Black | 0 | 0 | 1 | ± 20 | — | 85-A |
| Brown | 1 | 1 | 10 | — | 100 | 85-E |
| Red | 2 | 2 | 100 | — | 200 | — |
| Orange | 3 | 3 | 1,000 | ± 30 | 300 | — |
| Yellow | 4 | 4 | 10,000 | — | 400 | — |
| Green | 5 | 5 | — | — | 500 | — |
| Blue | 6 | 6 | — | — | 600 | — |
| Violet | 7 | 7 | — | — | 700 | — |
| Gray | 8 | 8 | — | — | 800 | — |
| White | 9 | 9 | — | — | 900 | — |
| Gold | — | — | — | — | 1,000 | — |
| Silver | — | — | — | ± 10 | — | — |

VOLTAGE RATING FOR RECTANGULAR CAPACITORS

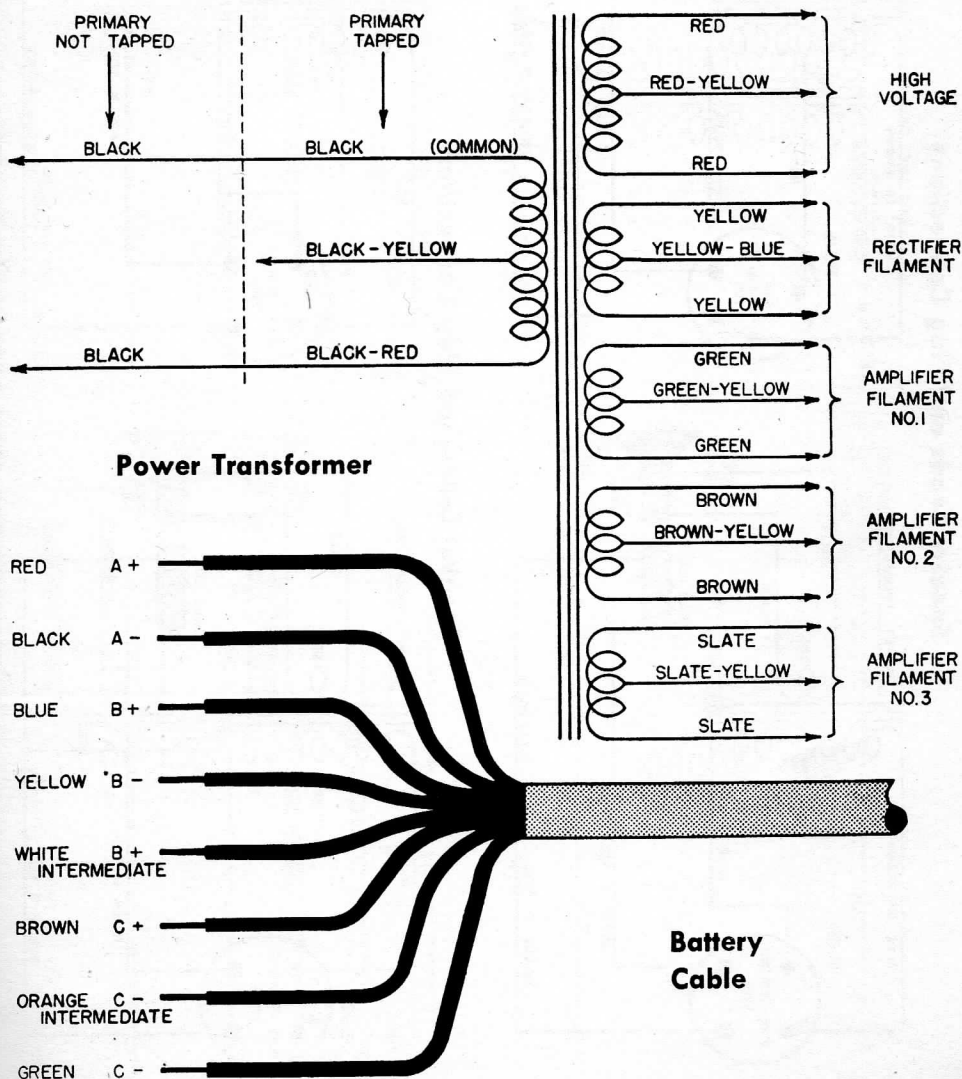
(Indicated by dimensions rather than color coding)

| Maximum Dimensions (inches) | | | Style C/N | Capacitance (μf) | Voltage Rating (v d-c) |
|--------------------------------|-----------------|------------------|--------------|---|----------------------------------|
| Length | Width | Thick- ness | | | |
| $5\frac{1}{64}$ | $1\frac{1}{32}$ | $\frac{7}{32}$ | 20 | 1000 2000-6000 10,000 | 400 200 120 |
| $5\frac{7}{64}$ | $3\frac{7}{64}$ | $1\frac{7}{64}$ | 22 | 2000-3000 6000-10,000 20,000 | 400 300 120 |
| $5\frac{3}{64}$ | $5\frac{3}{64}$ | $9\frac{1}{32}$ | 30 | 1000-2000 3000 6000-10,000 20,000 | 800 600 400 120 |
| $5\frac{3}{64}$ | $5\frac{3}{64}$ | $11\frac{1}{32}$ | 35 | 3000 6000-10,000 20,000 | 800 600 300 |
| $1\frac{1}{4}$ | $4\frac{1}{64}$ | $9\frac{1}{32}$ | 41 | 3000-6000 10,000 20,000 30,000 | 600 400 300 120 |
| $1\frac{13}{32}$ | $4\frac{9}{64}$ | $11\frac{1}{32}$ | 42 | 1000-6000 10,000-20,000 30,000 50,000 100,000 | 1000 600 400 300 120 |
| $1\frac{13}{32}$ | $4\frac{9}{64}$ | $13\frac{1}{32}$ | 43 | 10,000 20,000-30,000 50,000-100,000 200,000 | 1000 600 400 120 |

RETMA Color Codes

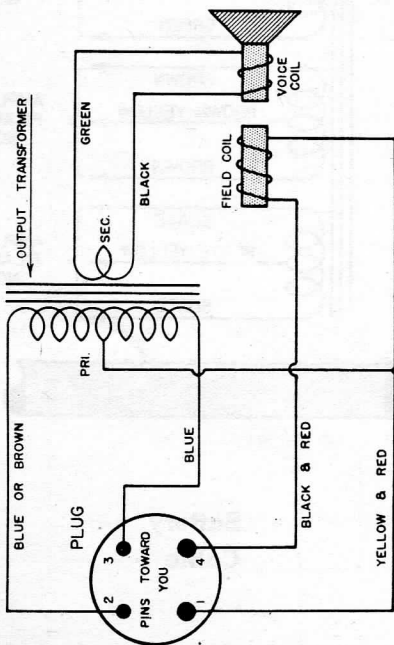
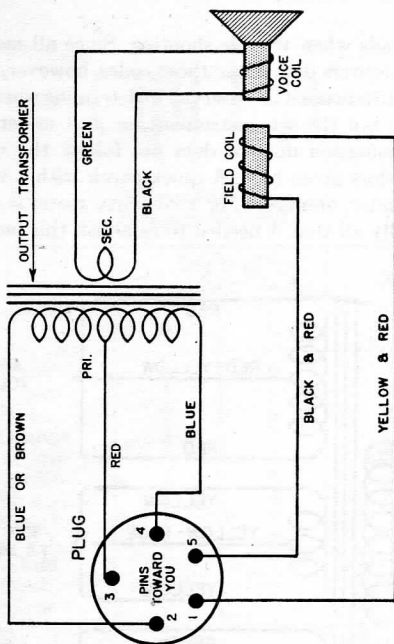
The color codes on the preceding and two following pages are used by most radio and instrument manufacturers in the wiring of their products, and by parts manufacturers for identifying lead placement or resistor and capacitor values, ratings, and tolerances. These have been included for whatever help they may provide in identifying parts and

leads when trouble-shooting. Since all manufacturers do not use these codes, however, due caution must be observed to determine whether or not the set, instrument, or part under examination does or does not follow the code colors given here. A quick check with a voltmeter, ohmmeter, or continuity meter is usually all that is needed to establish this fact.

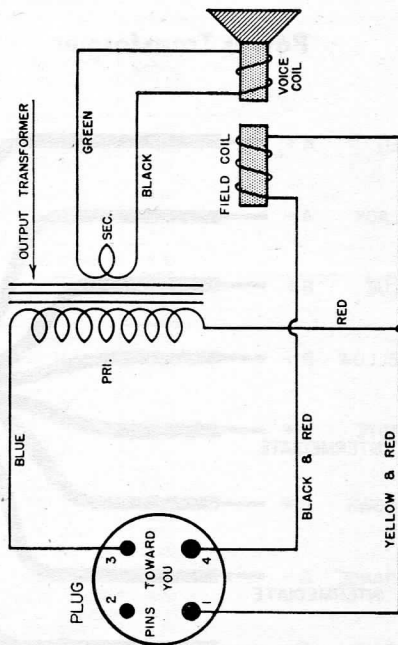
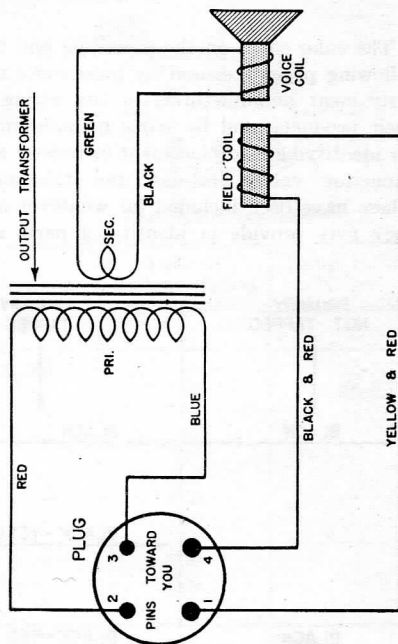


RETMA Color Codes—(Continued)

Speaker Leads and Plug Connections

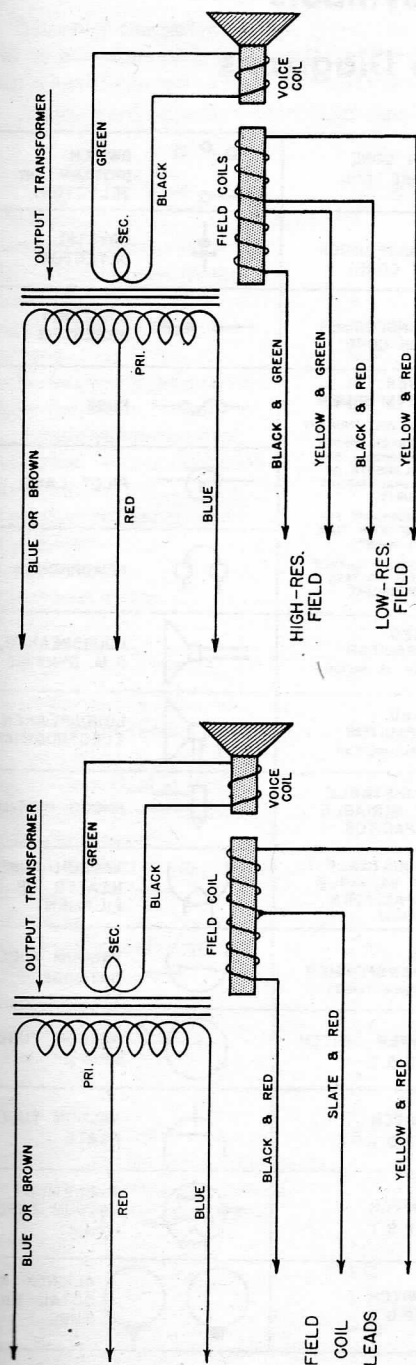


Speaker Leads and Plug Connections

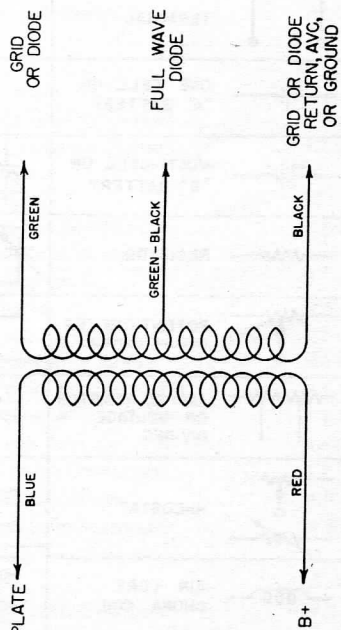


RETMA Color Codes—(Continued)

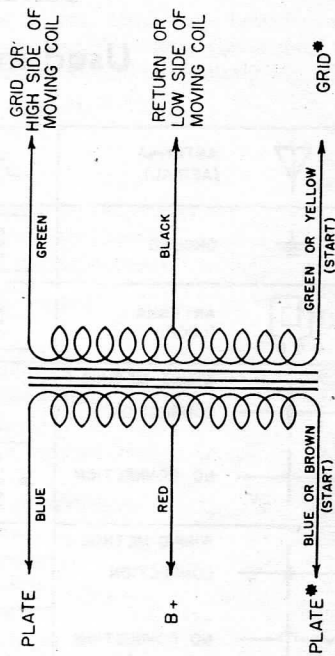
Speaker Lead Color Codes—(Continued)



I-F Transformers



Audio & Output Transformers



* FOUND ONLY ON PUSH-PULL PRIMARY OR SECONDARY WINDINGS

Schematic Symbols

Used in Radio Diagrams

| | | | | | |
|--|--|--|---|--|--------------------------------------|
| | ANTENNA (AERIAL) | | IRON CORE CHOKE COIL | | SWITCH (ROTARY OR SELECTOR) |
| | GROUND | | R.F. TRANSFORMER (AIR CORE) | | CRYSTAL DETECTOR |
| | ANTENNA (LOOP) | | A.F. TRANSFORMER (IRON CORE) | | LIGHTNING ARRESTER |
| | WIRING METHOD 1 CONNECTION | | POWER TRANSFORMER P-115 VOLT PRIMARY S1 - CENTER-TAPPED SECONDARY FOR FILAMENTS OF SIGNAL CIRCUIT TUBES S2 - SECONDARY FOR RECTIFIER TUBE FILAMENT S3 - CENTER-TAPPED HIGH-VOLTAGE SECONDARY | | FUSE |
| | NO CONNECTION | | | | PILOT LAMP |
| | WIRING METHOD 2 CONNECTION | | FIXED CAPACITOR (MICA OR PAPER) | | HEADPHONES |
| | NO CONNECTION | | | | LOUDSPEAKER, P. M. DYNAMIC |
| | TERMINAL | | FIXED CAPACITOR (ELECTROLYTIC) | | LOUDSPEAKER, ELECTRODYNAMIC |
| | ONE CELL OR "A" BATTERY | | ADJUSTABLE OR VARIABLE CAPACITOR | | PHONO PICK-UP |
| | MULTI-CELL OR "B" BATTERY | | ADJUSTABLE OR VARIABLE CAPACITORS (GANGED) | | VACUUM TUBE HEATER OR FILAMENT |
| | RESISTOR | | I.F. TRANSFORMER (DOUBLE-TUNED) | | VACUUM TUBE CATHODE |
| | POTENTIOMETER (VOLUME CONTROL) | | POWER SWITCH S. P. S. T. | | VACUUM TUBE GRID |
| | TAPPED RESISTOR OR VOLTAGE DIVIDER | | SWITCH S. P. D. T. | | VACUUM TUBE PLATE |
| | RHEOSTAT | | SWITCH D. P. S. T. | | 3-ELEMENT VACUUM TUBE (TRIODE) |
| | AIR CORE CHOKE COIL | | SWITCH D. P. D. T. | | ALIGNING KEY OCTAL BASE TUBE |

Abbreviations and Letter Symbols

Many of the abbreviations given are in lower-case letters. Obviously, however, there will be occasions such as when the abbreviations are used in titles where the original word would have been capitalized. In these cases, the abbreviation should be similarly capitalized.

A two-word adjective expression should contain a hyphen.

| <i>Term</i> | <i>Abbreviation</i> | <i>Term</i> | <i>Abbreviation</i> |
|-------------------------------------|----------------------|----------------------------------|---------------------|
| Admittance..... | <i>Y</i> | Low-frequency (adjective)..... | <i>l-f</i> |
| Alternating-current (adjective).... | <i>a-c</i> | Low frequency (noun)..... | <i>l.f.</i> |
| Alternating current (noun)..... | <i>a.c.</i> | Magnetic field intensity..... | <i>H</i> |
| Ampere..... | <i>a</i> | Megacycle..... | <i>Mc</i> |
| Angular velocity ($2\pi f$)..... | ω | Megohm..... | <i>M\Omega</i> |
| Antenna..... | <i>ant.</i> | Meter..... | <i>m</i> |
| Audio-frequency (adjective)..... | <i>a-f</i> | Microampere..... | μa |
| Audio-frequency (noun)..... | <i>a.f.</i> | Microfarad (mfd)..... | μf |
| Automatic volume control..... | <i>a.v.c.</i> | Microhenry..... | μh |
| Automatic volume expansion..... | <i>a.v.e.</i> | Micromicrofarad (mmfd)..... | $\mu\mu f$ |
| Capacitance..... | <i>C</i> | Microvolt..... | μv |
| Capacitive reactance..... | <i>X_C</i> | Microvolt per meter..... | $\mu v/m$ |
| Centimeter..... | <i>cm</i> | Microwatt..... | μw |
| Conductance..... | <i>G</i> | Milliampere..... | <i>ma</i> |
| Continuous waves..... | <i>c.w.</i> | Millihenry..... | <i>mh</i> |
| Current..... | <i>I, i</i> | Millivolt..... | <i>mv</i> |
| Cycles per second..... | \sim | Millivolt per meter..... | <i>mv/m</i> |
| Decibel..... | <i>db</i> | Milliwatt..... | <i>mw</i> |
| Direct-current (adjective)..... | <i>d-c</i> | Modulated contiguous waves..... | <i>m.c.w.</i> |
| Direct current (noun)..... | <i>d.c.</i> | Mutual inductance..... | <i>M</i> |
| Double cotton covered..... | <i>d.c.c.</i> | Ohm..... | Ω |
| Double pole, double throw..... | <i>d.p.d.t.</i> | Power..... | <i>P</i> |
| Double pole, single throw..... | <i>d.p.s.t.</i> | Power factor..... | <i>p.f.</i> |
| Double silk covered..... | <i>d.s.c.</i> | Radio-frequency (adjective)..... | <i>r-f</i> |
| Electric field intensity..... | <i>E</i> | Radio frequency (noun)..... | <i>r.f.</i> |
| Electromotive force..... | <i>e.m.f.</i> | Reactance..... | <i>X</i> |
| Frequency..... | <i>f</i> | Resistance..... | <i>R</i> |
| Frequency modulation..... | <i>f.m.</i> | Revolutions per minute..... | <i>r.p.m.</i> |
| Ground..... | <i>gnd.</i> | Root mean square..... | <i>r.m.s.</i> |
| Henry..... | <i>h</i> | Self-inductance..... | <i>L</i> |
| High-frequency (adjective)..... | <i>h-f</i> | Short wave..... | <i>s.w.</i> |
| High frequency (noun)..... | <i>h.f.</i> | Single cotton covered..... | <i>s.c.c.</i> |
| Impedance..... | <i>Z</i> | Single cotton enamel..... | <i>s.c.e.</i> |
| Inductance..... | <i>L</i> | Single pole, double throw..... | <i>s.p.d.t.</i> |
| Inductive reactance..... | <i>X_L</i> | Single pole, single throw..... | <i>s.p.s.t.</i> |
| Intermediate-frequency (adjective) | <i>i-f</i> | Single silk covered..... | <i>s.s.c.</i> |
| Intermediate frequency (noun).... | <i>i.f.</i> | Tuned radio frequency..... | <i>t.r.f.</i> |
| Interrupted continuous waves..... | <i>i.c.w.</i> | Ultra high frequency..... | <i>u.h.f.</i> |
| Kilocycle..... | <i>kc</i> | Vacuum tube voltmeter..... | <i>v.t.v.m</i> |
| Kilohm..... | <i>k\Omega</i> | Volt..... | <i>v</i> |
| Kilovolt..... | <i>kv</i> | Voltage..... | <i>E, e</i> |
| Kilovolt ampere..... | <i>kva</i> | Volt-Ohm-Milliammeter..... | <i>v.o.m.</i> |
| Kilowatt..... | <i>kw</i> | Watt..... | <i>w</i> |

Common Logarithms

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | N |
|----|------|------|------|------|------|------|------|------|------|------|----|
| 10 | 0000 | 0043 | 0086 | 0128 | 0170 | 0212 | 0253 | 0294 | 0334 | 0374 | 10 |
| 11 | 0414 | 0453 | 0492 | 0531 | 0569 | 0607 | 0645 | 0682 | 0719 | 0755 | 11 |
| 12 | 0792 | 0828 | 0864 | 0899 | 0934 | 0969 | 1004 | 1038 | 1072 | 1106 | 12 |
| 13 | 1139 | 1173 | 1206 | 1239 | 1271 | 1303 | 1335 | 1367 | 1399 | 1430 | 13 |
| 14 | 1461 | 1492 | 1523 | 1553 | 1584 | 1614 | 1644 | 1673 | 1703 | 1732 | 14 |
| 15 | 1761 | 1790 | 1818 | 1847 | 1875 | 1903 | 1931 | 1959 | 1987 | 2014 | 15 |
| 16 | 2041 | 2068 | 2095 | 2122 | 2148 | 2175 | 2201 | 2227 | 2253 | 2279 | 16 |
| 17 | 2304 | 2330 | 2355 | 2380 | 2405 | 2430 | 2455 | 2480 | 2504 | 2529 | 17 |
| 18 | 2553 | 2577 | 2601 | 2625 | 2648 | 2672 | 2695 | 2718 | 2742 | 2765 | 18 |
| 19 | 2788 | 2810 | 2833 | 2856 | 2878 | 2900 | 2923 | 2945 | 2967 | 2989 | 19 |
| 20 | 3010 | 3032 | 3054 | 3075 | 3096 | 3118 | 3139 | 3160 | 3181 | 3201 | 20 |
| 21 | 3222 | 3243 | 3263 | 3284 | 3304 | 3324 | 3345 | 3365 | 3385 | 3404 | 21 |
| 22 | 3424 | 3444 | 3464 | 3483 | 3502 | 3522 | 3541 | 3560 | 3579 | 3598 | 22 |
| 23 | 3617 | 3636 | 3655 | 3674 | 3692 | 3711 | 3729 | 3747 | 3766 | 3784 | 23 |
| 24 | 3802 | 3820 | 3838 | 3856 | 3874 | 3892 | 3909 | 3927 | 3945 | 3962 | 24 |
| 25 | 3979 | 3997 | 4014 | 4031 | 4048 | 4065 | 4082 | 4099 | 4116 | 4133 | 25 |
| 26 | 4150 | 4166 | 4183 | 4200 | 4216 | 4232 | 4249 | 4265 | 4281 | 4298 | 26 |
| 27 | 4314 | 4330 | 4346 | 4362 | 4378 | 4393 | 4409 | 4425 | 4440 | 4456 | 27 |
| 28 | 4472 | 4487 | 4502 | 4518 | 4533 | 4548 | 4564 | 4579 | 4594 | 4609 | 28 |
| 29 | 4624 | 4639 | 4654 | 4669 | 4683 | 4698 | 4713 | 4728 | 4742 | 4757 | 29 |
| 30 | 4771 | 4786 | 4800 | 4814 | 4829 | 4843 | 4857 | 4871 | 4886 | 4900 | 30 |
| 31 | 4914 | 4928 | 4942 | 4955 | 4969 | 4983 | 4997 | 5011 | 5024 | 5038 | 31 |
| 32 | 5051 | 5065 | 5079 | 5092 | 5105 | 5119 | 5132 | 5145 | 5159 | 5172 | 32 |
| 33 | 5185 | 5198 | 5211 | 5224 | 5237 | 5250 | 5263 | 5276 | 5289 | 5302 | 33 |
| 34 | 5315 | 5328 | 5340 | 5353 | 5366 | 5378 | 5391 | 5403 | 5416 | 5428 | 34 |
| 35 | 5441 | 5453 | 5465 | 5478 | 5490 | 5502 | 5514 | 5527 | 5539 | 5551 | 35 |
| 36 | 5563 | 5575 | 5587 | 5599 | 5611 | 5623 | 5635 | 5647 | 5658 | 5670 | 36 |
| 37 | 5682 | 5694 | 5705 | 5717 | 5729 | 5740 | 5752 | 5763 | 5775 | 5786 | 37 |
| 38 | 5798 | 5809 | 5821 | 5832 | 5843 | 5855 | 5866 | 5877 | 5888 | 5899 | 38 |
| 39 | 5911 | 5922 | 5933 | 5944 | 5955 | 5966 | 5977 | 5988 | 5999 | 6010 | 39 |
| 40 | 6021 | 6031 | 6042 | 6053 | 6064 | 6075 | 6085 | 6096 | 6107 | 6117 | 40 |
| 41 | 6128 | 6138 | 6149 | 6160 | 6170 | 6180 | 6191 | 6201 | 6212 | 6222 | 41 |
| 42 | 6232 | 6243 | 6253 | 6263 | 6274 | 6284 | 6294 | 6304 | 6314 | 6325 | 42 |
| 43 | 6335 | 6345 | 6355 | 6365 | 6375 | 6385 | 6395 | 6405 | 6415 | 6425 | 43 |
| 44 | 6435 | 6444 | 6454 | 6464 | 6474 | 6484 | 6493 | 6503 | 6513 | 6522 | 44 |
| 45 | 6532 | 6542 | 6551 | 6561 | 6571 | 6580 | 6590 | 6599 | 6609 | 6618 | 45 |
| 46 | 6628 | 6637 | 6646 | 6656 | 6665 | 6675 | 6684 | 6693 | 6702 | 6712 | 46 |
| 47 | 6721 | 6730 | 6739 | 6749 | 6758 | 6767 | 6776 | 6785 | 6794 | 6803 | 47 |
| 48 | 6812 | 6821 | 6830 | 6839 | 6848 | 6857 | 6866 | 6875 | 6884 | 6893 | 48 |
| 49 | 6902 | 6911 | 6920 | 6928 | 6937 | 6946 | 6955 | 6964 | 6972 | 6981 | 49 |
| 50 | 6990 | 6998 | 7007 | 7016 | 7024 | 7033 | 7042 | 7050 | 7059 | 7067 | 50 |
| 51 | 7076 | 7084 | 7093 | 7101 | 7110 | 7118 | 7126 | 7135 | 7143 | 7152 | 51 |
| 52 | 7160 | 7168 | 7177 | 7185 | 7193 | 7202 | 7210 | 7218 | 7226 | 7235 | 52 |
| 53 | 7243 | 7251 | 7259 | 7267 | 7275 | 7284 | 7292 | 7300 | 7308 | 7316 | 53 |
| 54 | 7324 | 7332 | 7340 | 7348 | 7356 | 7364 | 7372 | 7380 | 7388 | 7396 | 54 |
| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | N |

Common Logarithms (Continued)

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | N |
|----|------|------|------|------|------|------|------|------|------|------|----|
| 55 | 7404 | 7412 | 7419 | 7427 | 7435 | 7443 | 7451 | 7459 | 7466 | 7474 | 55 |
| 56 | 7482 | 7490 | 7497 | 7505 | 7513 | 7520 | 7528 | 7536 | 7543 | 7551 | 56 |
| 57 | 7559 | 7566 | 7574 | 7582 | 7589 | 7597 | 7604 | 7612 | 7619 | 7627 | 57 |
| 58 | 7634 | 7642 | 7649 | 7657 | 7664 | 7672 | 7679 | 7686 | 7694 | 7701 | 58 |
| 59 | 7709 | 7716 | 7723 | 7731 | 7738 | 7745 | 7752 | 7760 | 7767 | 7774 | 59 |
| 60 | 7782 | 7789 | 7796 | 7803 | 7810 | 7818 | 7825 | 7832 | 7839 | 7846 | 60 |
| 61 | 7853 | 7860 | 7868 | 7875 | 7882 | 7889 | 7896 | 7903 | 7910 | 7917 | 61 |
| 62 | 7924 | 7931 | 7938 | 7945 | 7952 | 7959 | 7966 | 7973 | 7980 | 7987 | 62 |
| 63 | 7993 | 8000 | 8007 | 8014 | 8021 | 8028 | 8035 | 8041 | 8048 | 8055 | 63 |
| 64 | 8062 | 8069 | 8075 | 8082 | 8089 | 8096 | 8102 | 8109 | 8116 | 8122 | 64 |
| 65 | 8129 | 8136 | 8142 | 8149 | 8156 | 8162 | 8169 | 8176 | 8182 | 8189 | 65 |
| 66 | 8195 | 8202 | 8209 | 8215 | 8222 | 8228 | 8235 | 8241 | 8248 | 8254 | 66 |
| 67 | 8261 | 8267 | 8274 | 8280 | 8287 | 8293 | 8299 | 8306 | 8312 | 8319 | 67 |
| 68 | 8325 | 8331 | 8338 | 8344 | 8351 | 8357 | 8363 | 8370 | 8376 | 8382 | 68 |
| 69 | 8388 | 8395 | 8401 | 8407 | 8414 | 8420 | 8426 | 8432 | 8439 | 8445 | 69 |
| 70 | 8451 | 8457 | 8463 | 8470 | 8476 | 8482 | 8488 | 8494 | 8500 | 8506 | 70 |
| 71 | 8513 | 8519 | 8525 | 8531 | 8537 | 8543 | 8549 | 8555 | 8561 | 8567 | 71 |
| 72 | 8573 | 8579 | 8585 | 8591 | 8597 | 8603 | 8609 | 8615 | 8621 | 8627 | 72 |
| 73 | 8633 | 8639 | 8645 | 8651 | 8657 | 8663 | 8669 | 8675 | 8681 | 8686 | 73 |
| 74 | 8692 | 8698 | 8704 | 8710 | 8716 | 8722 | 8727 | 8733 | 8739 | 8745 | 74 |
| 75 | 8751 | 8756 | 8762 | 8768 | 8774 | 8779 | 8785 | 8791 | 8797 | 8802 | 75 |
| 76 | 8808 | 8814 | 8820 | 8825 | 8831 | 8837 | 8842 | 8848 | 8854 | 8859 | 76 |
| 77 | 8865 | 8871 | 8876 | 8882 | 8887 | 8893 | 8899 | 8904 | 8910 | 8915 | 77 |
| 78 | 8921 | 8927 | 8932 | 8938 | 8943 | 8949 | 8954 | 8960 | 8965 | 8971 | 78 |
| 79 | 8976 | 8982 | 8987 | 8993 | 8998 | 9004 | 9009 | 9015 | 9020 | 9025 | 79 |
| 80 | 9031 | 9036 | 9042 | 9047 | 9053 | 9058 | 9063 | 9069 | 9074 | 9079 | 80 |
| 81 | 9085 | 9090 | 9096 | 9101 | 9106 | 9112 | 9117 | 9122 | 9128 | 9133 | 81 |
| 82 | 9138 | 9143 | 9149 | 9154 | 9159 | 9165 | 9170 | 9175 | 9180 | 9186 | 82 |
| 83 | 9191 | 9196 | 9201 | 9206 | 9212 | 9217 | 9222 | 9227 | 9232 | 9238 | 83 |
| 84 | 9243 | 9248 | 9253 | 9258 | 9263 | 9269 | 9274 | 9279 | 9284 | 9289 | 84 |
| 85 | 9294 | 9299 | 9304 | 9309 | 9315 | 9320 | 9325 | 9330 | 9335 | 9340 | 85 |
| 86 | 9345 | 9350 | 9355 | 9360 | 9365 | 9370 | 9375 | 9380 | 9385 | 9390 | 86 |
| 87 | 9395 | 9400 | 9405 | 9410 | 9415 | 9420 | 9425 | 9430 | 9435 | 9440 | 87 |
| 88 | 9445 | 9450 | 9455 | 9460 | 9465 | 9469 | 9474 | 9479 | 9484 | 9489 | 88 |
| 89 | 9494 | 9499 | 9504 | 9509 | 9513 | 9518 | 9523 | 9528 | 9533 | 9538 | 89 |
| 90 | 9542 | 9547 | 9552 | 9557 | 9562 | 9566 | 9571 | 9576 | 9581 | 9586 | 90 |
| 91 | 9590 | 9595 | 9600 | 9605 | 9609 | 9614 | 9619 | 9624 | 9628 | 9633 | 91 |
| 92 | 9638 | 9643 | 9647 | 9652 | 9657 | 9661 | 9666 | 9671 | 9675 | 9680 | 92 |
| 93 | 9685 | 9689 | 9694 | 9699 | 9703 | 9708 | 9713 | 9717 | 9722 | 9727 | 93 |
| 94 | 9731 | 9736 | 9741 | 9745 | 9750 | 9754 | 9759 | 9763 | 9768 | 9773 | 94 |
| 95 | 9777 | 9782 | 9786 | 9791 | 9795 | 9800 | 9805 | 9809 | 9814 | 9818 | 95 |
| 96 | 9823 | 9827 | 9832 | 9836 | 9841 | 9845 | 9850 | 9854 | 9859 | 9863 | 96 |
| 97 | 9868 | 9872 | 9877 | 9881 | 9886 | 9890 | 9894 | 9899 | 9903 | 9908 | 97 |
| 98 | 9912 | 9917 | 9921 | 9926 | 9930 | 9934 | 9939 | 9943 | 9948 | 9952 | 98 |
| 99 | 9956 | 9961 | 9965 | 9969 | 9974 | 9978 | 9983 | 9987 | 9991 | 9996 | 99 |
| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | N |

Natural Sines, Cosines, and Tangents

0°-14.9°

| Degs. | Function | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° |
|-------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0 | sin | 0.0000 | 0.0017 | 0.0035 | 0.0052 | 0.0070 | 0.0087 | 0.0105 | 0.0122 | 0.0140 | 0.0157 |
| | cos | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 0.9999 | 0.9999 | 0.9999 |
| | tan | 0.0000 | 0.0017 | 0.0035 | 0.0052 | 0.0070 | 0.0087 | 0.0105 | 0.0122 | 0.0140 | 0.0157 |
| 1 | sin | 0.0175 | 0.0192 | 0.0209 | 0.0227 | 0.0244 | 0.0262 | 0.0279 | 0.0297 | 0.0314 | 0.0332 |
| | cos | 0.9998 | 0.9998 | 0.9998 | 0.9997 | 0.9997 | 0.9997 | 0.9996 | 0.9996 | 0.9995 | 0.9995 |
| | tan | 0.0175 | 0.0192 | 0.0209 | 0.0227 | 0.0244 | 0.0262 | 0.0279 | 0.0297 | 0.0314 | 0.0332 |
| 2 | sin | 0.0349 | 0.0366 | 0.0384 | 0.0401 | 0.0419 | 0.0436 | 0.0454 | 0.0471 | 0.0488 | 0.0506 |
| | cos | 0.9994 | 0.9993 | 0.9993 | 0.9992 | 0.9991 | 0.9990 | 0.9990 | 0.9989 | 0.9988 | 0.9987 |
| | tan | 0.0349 | 0.0367 | 0.0384 | 0.0402 | 0.0419 | 0.0437 | 0.0454 | 0.0472 | 0.0489 | 0.0507 |
| 3 | sin | 0.0523 | 0.0541 | 0.0558 | 0.0576 | 0.0593 | 0.0610 | 0.0628 | 0.0645 | 0.0663 | 0.0680 |
| | cos | 0.9986 | 0.9985 | 0.9984 | 0.9983 | 0.9982 | 0.9981 | 0.9980 | 0.9979 | 0.9978 | 0.9977 |
| | tan | 0.0524 | 0.0542 | 0.0559 | 0.0577 | 0.0594 | 0.0612 | 0.0629 | 0.0647 | 0.0664 | 0.0682 |
| 4 | sin | 0.0698 | 0.0715 | 0.0732 | 0.0750 | 0.0767 | 0.0785 | 0.0802 | 0.0819 | 0.0837 | 0.0854 |
| | cos | 0.9976 | 0.9974 | 0.9973 | 0.9972 | 0.9971 | 0.9969 | 0.9968 | 0.9966 | 0.9965 | 0.9963 |
| | tan | 0.0699 | 0.0717 | 0.0734 | 0.0752 | 0.0769 | 0.0787 | 0.0805 | 0.0822 | 0.0840 | 0.0857 |
| 5 | sin | 0.0872 | 0.0889 | 0.0906 | 0.0924 | 0.0941 | 0.0958 | 0.0976 | 0.0993 | 0.1011 | 0.1028 |
| | cos | 0.9962 | 0.9960 | 0.9959 | 0.9957 | 0.9956 | 0.9954 | 0.9952 | 0.9951 | 0.9949 | 0.9947 |
| | tan | 0.0875 | 0.0892 | 0.0910 | 0.0928 | 0.0945 | 0.0963 | 0.0981 | 0.0998 | 0.1016 | 0.1033 |
| 6 | sin | 0.1045 | 0.1063 | 0.1080 | 0.1097 | 0.1115 | 0.1132 | 0.1149 | 0.1167 | 0.1184 | 0.1201 |
| | cos | 0.9945 | 0.9943 | 0.9942 | 0.9940 | 0.9938 | 0.9936 | 0.9934 | 0.9932 | 0.9930 | 0.9928 |
| | tan | 0.1051 | 0.1069 | 0.1086 | 0.1104 | 0.1122 | 0.1139 | 0.1157 | 0.1175 | 0.1192 | 0.1210 |
| 7 | sin | 0.1219 | 0.1236 | 0.1253 | 0.1271 | 0.1288 | 0.1305 | 0.1323 | 0.1340 | 0.1357 | 0.1374 |
| | cos | 0.9925 | 0.9923 | 0.9921 | 0.9919 | 0.9917 | 0.9914 | 0.9912 | 0.9910 | 0.9907 | 0.9905 |
| | tan | 0.1228 | 0.1246 | 0.1263 | 0.1281 | 0.1299 | 0.1317 | 0.1334 | 0.1352 | 0.1370 | 0.1388 |
| 8 | sin | 0.1392 | 0.1409 | 0.1426 | 0.1444 | 0.1461 | 0.1478 | 0.1495 | 0.1513 | 0.1530 | 0.1547 |
| | cos | 0.9903 | 0.9900 | 0.9898 | 0.9895 | 0.9893 | 0.9890 | 0.9888 | 0.9885 | 0.9882 | 0.9880 |
| | tan | 0.1405 | 0.1423 | 0.1441 | 0.1459 | 0.1477 | 0.1495 | 0.1512 | 0.1530 | 0.1548 | 0.1566 |
| 9 | sin | 0.1564 | 0.1582 | 0.1599 | 0.1616 | 0.1633 | 0.1650 | 0.1668 | 0.1685 | 0.1702 | 0.1719 |
| | cos | 0.9877 | 0.9874 | 0.9871 | 0.9869 | 0.9866 | 0.9863 | 0.9860 | 0.9857 | 0.9854 | 0.9851 |
| | tan | 0.1584 | 0.1602 | 0.1620 | 0.1638 | 0.1655 | 0.1673 | 0.1691 | 0.1709 | 0.1727 | 0.1745 |
| 10 | sin | 0.1736 | 0.1754 | 0.1771 | 0.1788 | 0.1805 | 0.1822 | 0.1840 | 0.1857 | 0.1874 | 0.1891 |
| | cos | 0.9848 | 0.9845 | 0.9842 | 0.9839 | 0.9836 | 0.9833 | 0.9829 | 0.9826 | 0.9823 | 0.9820 |
| | tan | 0.1763 | 0.1781 | 0.1799 | 0.1817 | 0.1835 | 0.1853 | 0.1871 | 0.1890 | 0.1908 | 0.1926 |
| 11 | sin | 0.1908 | 0.1925 | 0.1942 | 0.1959 | 0.1977 | 0.1994 | 0.2011 | 0.2028 | 0.2045 | 0.2062 |
| | cos | 0.9816 | 0.9813 | 0.9810 | 0.9806 | 0.9803 | 0.9799 | 0.9796 | 0.9792 | 0.9789 | 0.9785 |
| | tan | 0.1944 | 0.1962 | 0.1980 | 0.1998 | 0.2016 | 0.2035 | 0.2053 | 0.2071 | 0.2089 | 0.2107 |
| 12 | sin | 0.2079 | 0.2096 | 0.2113 | 0.2130 | 0.2147 | 0.2164 | 0.2181 | 0.2198 | 0.2215 | 0.2232 |
| | cos | 0.9781 | 0.9778 | 0.9774 | 0.9770 | 0.9767 | 0.9763 | 0.9759 | 0.9755 | 0.9751 | 0.9748 |
| | tan | 0.2126 | 0.2144 | 0.2162 | 0.2180 | 0.2199 | 0.2217 | 0.2235 | 0.2254 | 0.2272 | 0.2290 |
| 13 | sin | 0.2250 | 0.2267 | 0.2284 | 0.2300 | 0.2318 | 0.2334 | 0.2351 | 0.2368 | 0.2385 | 0.2402 |
| | cos | 0.9744 | 0.9740 | 0.9736 | 0.9732 | 0.9728 | 0.9724 | 0.9720 | 0.9715 | 0.9711 | 0.9707 |
| | tan | 0.2309 | 0.2327 | 0.2345 | 0.2364 | 0.2382 | 0.2401 | 0.2419 | 0.2438 | 0.2456 | 0.2475 |
| 14 | sin | 0.2419 | 0.2436 | 0.2453 | 0.2470 | 0.2487 | 0.2504 | 0.2521 | 0.2538 | 0.2554 | 0.2571 |
| | cos | 0.9703 | 0.9699 | 0.9694 | 0.9690 | 0.9686 | 0.9681 | 0.9677 | 0.9673 | 0.9668 | 0.9664 |
| | tan | 0.2493 | 0.2512 | 0.2530 | 0.2549 | 0.2568 | 0.2586 | 0.2605 | 0.2623 | 0.2642 | 0.2661 |
| Degs. | Function | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' |

Natural Sines, Cosines, and Tangents—(Continued)

15°-29.9°

| Degs. | Function | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° |
|-------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 15 | sin | 0.2588 | 0.2605 | 0.2622 | 0.2639 | 0.2656 | 0.2672 | 0.2689 | 0.2706 | 0.2723 | 0.2740 |
| | cos | 0.9659 | 0.9655 | 0.9650 | 0.9646 | 0.9641 | 0.9636 | 0.9632 | 0.9627 | 0.9622 | 0.9617 |
| | tan | 0.2679 | 0.2698 | 0.2717 | 0.2736 | 0.2754 | 0.2773 | 0.2792 | 0.2811 | 0.2830 | 0.2849 |
| 16 | sin | 0.2756 | 0.2773 | 0.2790 | 0.2807 | 0.2823 | 0.2840 | 0.2857 | 0.2874 | 0.2890 | 0.2907 |
| | cos | 0.9613 | 0.9608 | 0.9603 | 0.9598 | 0.9593 | 0.9588 | 0.9583 | 0.9578 | 0.9573 | 0.9568 |
| | tan | 0.2867 | 0.2886 | 0.2905 | 0.2924 | 0.2943 | 0.2962 | 0.2981 | 0.3000 | 0.3019 | 0.3038 |
| 17 | sin | 0.2924 | 0.2940 | 0.2957 | 0.2974 | 0.2990 | 0.3007 | 0.3024 | 0.3040 | 0.3057 | 0.3074 |
| | cos | 0.9563 | 0.9558 | 0.9553 | 0.9548 | 0.9542 | 0.9537 | 0.9532 | 0.9527 | 0.9521 | 0.9516 |
| | tan | 0.3057 | 0.3076 | 0.3096 | 0.3115 | 0.3134 | 0.3153 | 0.3172 | 0.3191 | 0.3211 | 0.3230 |
| 18 | sin | 0.3090 | 0.3107 | 0.3123 | 0.3140 | 0.3156 | 0.3173 | 0.3190 | 0.3206 | 0.3223 | 0.3239 |
| | cos | 0.9511 | 0.9505 | 0.9500 | 0.9494 | 0.9489 | 0.9483 | 0.9478 | 0.9472 | 0.9466 | 0.9461 |
| | tan | 0.3249 | 0.3269 | 0.3288 | 0.3307 | 0.3327 | 0.3346 | 0.3365 | 0.3385 | 0.3404 | 0.3424 |
| 19 | sin | 0.3256 | 0.3272 | 0.3289 | 0.3305 | 0.3322 | 0.3338 | 0.3355 | 0.3371 | 0.3387 | 0.3404 |
| | cos | 0.9455 | 0.9449 | 0.9444 | 0.9438 | 0.9432 | 0.9426 | 0.9421 | 0.9415 | 0.9409 | 0.9403 |
| | tan | 0.3443 | 0.3463 | 0.3482 | 0.3502 | 0.3522 | 0.3541 | 0.3561 | 0.3581 | 0.3600 | 0.3620 |
| 20 | sin | 0.3420 | 0.3437 | 0.3453 | 0.3469 | 0.3486 | 0.3502 | 0.3518 | 0.3535 | 0.3551 | 0.3567 |
| | cos | 0.9397 | 0.9391 | 0.9385 | 0.9379 | 0.9373 | 0.9367 | 0.9361 | 0.9354 | 0.9348 | 0.9342 |
| | tan | 0.3640 | 0.3659 | 0.3679 | 0.3699 | 0.3719 | 0.3739 | 0.3759 | 0.3779 | 0.3799 | 0.3819 |
| 21 | sin | 0.3584 | 0.3600 | 0.3616 | 0.3633 | 0.3649 | 0.3665 | 0.3681 | 0.3697 | 0.3714 | 0.3730 |
| | cos | 0.9336 | 0.9330 | 0.9323 | 0.9317 | 0.9311 | 0.9304 | 0.9298 | 0.9291 | 0.9285 | 0.9278 |
| | tan | 0.3839 | 0.3859 | 0.3879 | 0.3899 | 0.3919 | 0.3939 | 0.3959 | 0.3979 | 0.4000 | 0.4020 |
| 22 | sin | 0.3746 | 0.3762 | 0.3778 | 0.3795 | 0.3811 | 0.3827 | 0.3843 | 0.3859 | 0.3875 | 0.3891 |
| | cos | 0.9272 | 0.9265 | 0.9259 | 0.9252 | 0.9245 | 0.9239 | 0.9232 | 0.9225 | 0.9219 | 0.9212 |
| | tan | 0.4040 | 0.4061 | 0.4081 | 0.4101 | 0.4122 | 0.4142 | 0.4163 | 0.4183 | 0.4204 | 0.4224 |
| 23 | sin | 0.3907 | 0.3923 | 0.3939 | 0.3955 | 0.3971 | 0.3987 | 0.4003 | 0.4019 | 0.4035 | 0.4051 |
| | cos | 0.9205 | 0.9198 | 0.9191 | 0.9184 | 0.9178 | 0.9171 | 0.9164 | 0.9157 | 0.9150 | 0.9143 |
| | tan | 0.4245 | 0.4265 | 0.4286 | 0.4307 | 0.4327 | 0.4348 | 0.4369 | 0.4390 | 0.4411 | 0.4431 |
| 24 | sin | 0.4067 | 0.4083 | 0.4099 | 0.4115 | 0.4131 | 0.4147 | 0.4163 | 0.4179 | 0.4195 | 0.4210 |
| | cos | 0.9135 | 0.9128 | 0.9121 | 0.9114 | 0.9107 | 0.9100 | 0.9092 | 0.9085 | 0.9078 | 0.9070 |
| | tan | 0.4452 | 0.4473 | 0.4494 | 0.4515 | 0.4536 | 0.4557 | 0.4578 | 0.4599 | 0.4621 | 0.4642 |
| 25 | sin | 0.4226 | 0.4242 | 0.4258 | 0.4274 | 0.4289 | 0.4305 | 0.4321 | 0.4337 | 0.4352 | 0.4368 |
| | cos | 0.9063 | 0.9056 | 0.9048 | 0.9041 | 0.9033 | 0.9026 | 0.9018 | 0.9011 | 0.9003 | 0.8996 |
| | tan | 0.4663 | 0.4684 | 0.4706 | 0.4727 | 0.4748 | 0.4770 | 0.4791 | 0.4813 | 0.4834 | 0.4856 |
| 26 | sin | 0.4384 | 0.4399 | 0.4415 | 0.4431 | 0.4446 | 0.4462 | 0.4478 | 0.4493 | 0.4509 | 0.4524 |
| | cos | 0.8988 | 0.8980 | 0.8973 | 0.8965 | 0.8957 | 0.8949 | 0.8942 | 0.8934 | 0.8926 | 0.8918 |
| | tan | 0.4877 | 0.4899 | 0.4921 | 0.4942 | 0.4964 | 0.4986 | 0.5008 | 0.5029 | 0.5051 | 0.5073 |
| 27 | sin | 0.4540 | 0.4555 | 0.4571 | 0.4586 | 0.4602 | 0.4617 | 0.4633 | 0.4648 | 0.4664 | 0.4679 |
| | cos | 0.8910 | 0.8902 | 0.8894 | 0.8886 | 0.8878 | 0.8870 | 0.8862 | 0.8854 | 0.8846 | 0.8838 |
| | tan | 0.5095 | 0.5117 | 0.5139 | 0.5161 | 0.5184 | 0.5206 | 0.5228 | 0.5250 | 0.5272 | 0.5295 |
| 28 | sin | 0.4695 | 0.4710 | 0.4726 | 0.4741 | 0.4756 | 0.4772 | 0.4787 | 0.4802 | 0.4818 | 0.4833 |
| | cos | 0.8829 | 0.8821 | 0.8813 | 0.8805 | 0.8796 | 0.8788 | 0.8780 | 0.8771 | 0.8763 | 0.8755 |
| | tan | 0.5317 | 0.5340 | 0.5362 | 0.5384 | 0.5407 | 0.5430 | 0.5452 | 0.5475 | 0.5498 | 0.5520 |
| 29 | sin | 0.4848 | 0.4863 | 0.4879 | 0.4894 | 0.4909 | 0.4924 | 0.4939 | 0.4955 | 0.4970 | 0.4985 |
| | cos | 0.8746 | 0.8738 | 0.8729 | 0.8721 | 0.8712 | 0.8704 | 0.8695 | 0.8686 | 0.8678 | 0.8669 |
| | tan | 0.5543 | 0.5566 | 0.5589 | 0.5612 | 0.5635 | 0.5658 | 0.5681 | 0.5704 | 0.5727 | 0.5750 |
| Degs. | Function | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' |

Natural Sines, Cosines, and Tangents—(Continued)

30°-44.9°

| Degs. | Function | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° |
|-------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 30 | sin | 0.5000 | 0.5015 | 0.5030 | 0.5045 | 0.5060 | 0.5075 | 0.5090 | 0.5105 | 0.5120 | 0.5135 |
| | cos | 0.8660 | 0.8652 | 0.8643 | 0.8634 | 0.8625 | 0.8616 | 0.8607 | 0.8599 | 0.8590 | 0.8581 |
| | tan | 0.5774 | 0.5797 | 0.5820 | 0.5844 | 0.5867 | 0.5890 | 0.5914 | 0.5938 | 0.5961 | 0.5985 |
| 31 | sin | 0.5150 | 0.5165 | 0.5180 | 0.5195 | 0.5210 | 0.5225 | 0.5240 | 0.5255 | 0.5270 | 0.5284 |
| | cos | 0.8572 | 0.8563 | 0.8554 | 0.8545 | 0.8536 | 0.8526 | 0.8517 | 0.8508 | 0.8499 | 0.8490 |
| | tan | 0.6009 | 0.6032 | 0.6056 | 0.6080 | 0.6104 | 0.6128 | 0.6152 | 0.6176 | 0.6200 | 0.6224 |
| 32 | sin | 0.5299 | 0.5314 | 0.5329 | 0.5344 | 0.5358 | 0.5373 | 0.5388 | 0.5402 | 0.5417 | 0.5432 |
| | cos | 0.8480 | 0.8471 | 0.8462 | 0.8453 | 0.8443 | 0.8434 | 0.8425 | 0.8415 | 0.8406 | 0.8396 |
| | tan | 0.6249 | 0.6273 | 0.6297 | 0.6322 | 0.6346 | 0.6371 | 0.6395 | 0.6420 | 0.6445 | 0.6469 |
| 33 | sin | 0.5446 | 0.5461 | 0.5476 | 0.5490 | 0.5505 | 0.5519 | 0.5534 | 0.5548 | 0.5563 | 0.5577 |
| | cos | 0.8387 | 0.8377 | 0.8368 | 0.8358 | 0.8348 | 0.8339 | 0.8329 | 0.8320 | 0.8310 | 0.8300 |
| | tan | 0.6494 | 0.6519 | 0.6544 | 0.6569 | 0.6594 | 0.6619 | 0.6644 | 0.6669 | 0.6694 | 0.6720 |
| 34 | sin | 0.5592 | 0.5606 | 0.5621 | 0.5635 | 0.5650 | 0.5664 | 0.5678 | 0.5693 | 0.5707 | 0.5721 |
| | cos | 0.8290 | 0.8281 | 0.8271 | 0.8261 | 0.8251 | 0.8241 | 0.8231 | 0.8221 | 0.8211 | 0.8202 |
| | tan | 0.6745 | 0.6771 | 0.6796 | 0.6822 | 0.6847 | 0.6873 | 0.6899 | 0.6924 | 0.6950 | 0.6976 |
| 35 | sin | 0.5736 | 0.5750 | 0.5764 | 0.5779 | 0.5793 | 0.5807 | 0.5821 | 0.5835 | 0.5850 | 0.5864 |
| | cos | 0.8192 | 0.8181 | 0.8171 | 0.8161 | 0.8151 | 0.8141 | 0.8131 | 0.8121 | 0.8111 | 0.8100 |
| | tan | 0.7002 | 0.7028 | 0.7054 | 0.7080 | 0.7107 | 0.7133 | 0.7159 | 0.7186 | 0.7212 | 0.7239 |
| 36 | sin | 0.5878 | 0.5892 | 0.5906 | 0.5920 | 0.5934 | 0.5948 | 0.5962 | 0.5976 | 0.5990 | 0.6004 |
| | cos | 0.8090 | 0.8080 | 0.8070 | 0.8059 | 0.8049 | 0.8039 | 0.8028 | 0.8018 | 0.8007 | 0.7997 |
| | tan | 0.7265 | 0.7292 | 0.7319 | 0.7346 | 0.7373 | 0.7400 | 0.7427 | 0.7454 | 0.7481 | 0.7508 |
| 37 | sin | 0.6018 | 0.6032 | 0.6046 | 0.6060 | 0.6074 | 0.6088 | 0.6101 | 0.6115 | 0.6129 | 0.6143 |
| | cos | 0.7986 | 0.7976 | 0.7965 | 0.7955 | 0.7944 | 0.7934 | 0.7923 | 0.7912 | 0.7902 | 0.7891 |
| | tan | 0.7536 | 0.7563 | 0.7590 | 0.7618 | 0.7646 | 0.7673 | 0.7701 | 0.7729 | 0.7757 | 0.7785 |
| 38 | sin | 0.6157 | 0.6170 | 0.6184 | 0.6198 | 0.6211 | 0.6225 | 0.6239 | 0.6252 | 0.6266 | 0.6280 |
| | cos | 0.7880 | 0.7869 | 0.7859 | 0.7848 | 0.7837 | 0.7826 | 0.7815 | 0.7804 | 0.7793 | 0.7782 |
| | tan | 0.7813 | 0.7841 | 0.7869 | 0.7898 | 0.7926 | 0.7954 | 0.7983 | 0.8012 | 0.8040 | 0.8069 |
| 39 | sin | 0.6293 | 0.6307 | 0.6320 | 0.6334 | 0.6347 | 0.6361 | 0.6374 | 0.6388 | 0.6401 | 0.6414 |
| | cos | 0.7771 | 0.7760 | 0.7749 | 0.7738 | 0.7727 | 0.7716 | 0.7705 | 0.7694 | 0.7683 | 0.7672 |
| | tan | 0.8098 | 0.8127 | 0.8156 | 0.8185 | 0.8214 | 0.8243 | 0.8273 | 0.8302 | 0.8332 | 0.8361 |
| 40 | sin | 0.6428 | 0.6441 | 0.6455 | 0.6468 | 0.6481 | 0.6494 | 0.6508 | 0.6521 | 0.6534 | 0.6547 |
| | cos | 0.7660 | 0.7649 | 0.7638 | 0.7627 | 0.7615 | 0.7604 | 0.7593 | 0.7581 | 0.7570 | 0.7559 |
| | tan | 0.8391 | 0.8421 | 0.8451 | 0.8481 | 0.8511 | 0.8541 | 0.8571 | 0.8601 | 0.8632 | 0.8662 |
| 41 | sin | 0.6561 | 0.6574 | 0.6587 | 0.6600 | 0.6613 | 0.6626 | 0.6639 | 0.6652 | 0.6665 | 0.6678 |
| | cos | 0.7547 | 0.7536 | 0.7524 | 0.7513 | 0.7501 | 0.7490 | 0.7478 | 0.7466 | 0.7455 | 0.7443 |
| | tan | 0.8693 | 0.8724 | 0.8754 | 0.8785 | 0.8816 | 0.8847 | 0.8878 | 0.8910 | 0.8941 | 0.8972 |
| 42 | sin | 0.6691 | 0.6704 | 0.6717 | 0.6730 | 0.6743 | 0.6756 | 0.6769 | 0.6782 | 0.6794 | 0.6807 |
| | cos | 0.7431 | 0.7420 | 0.7408 | 0.7396 | 0.7385 | 0.7373 | 0.7361 | 0.7349 | 0.7337 | 0.7325 |
| | tan | 0.9004 | 0.9036 | 0.9067 | 0.9099 | 0.9131 | 0.9163 | 0.9195 | 0.9228 | 0.9260 | 0.9293 |
| 43 | sin | 0.6820 | 0.6833 | 0.6845 | 0.6858 | 0.6871 | 0.6884 | 0.6896 | 0.6909 | 0.6921 | 0.6934 |
| | cos | 0.7314 | 0.7302 | 0.7290 | 0.7278 | 0.7266 | 0.7254 | 0.7242 | 0.7230 | 0.7218 | 0.7206 |
| | tan | 0.9325 | 0.9358 | 0.9391 | 0.9424 | 0.9457 | 0.9490 | 0.9523 | 0.9556 | 0.9590 | 0.9623 |
| 44 | sin | 0.6947 | 0.6959 | 0.6972 | 0.6984 | 0.6997 | 0.7009 | 0.7022 | 0.7034 | 0.7046 | 0.7059 |
| | cos | 0.7193 | 0.7181 | 0.7169 | 0.7157 | 0.7145 | 0.7133 | 0.7120 | 0.7108 | 0.7096 | 0.7083 |
| | tan | 0.9657 | 0.9691 | 0.9725 | 0.9759 | 0.9793 | 0.9827 | 0.9861 | 0.9896 | 0.9930 | 0.9965 |
| Degs. | Function | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' |

Natural Sines, Cosines, and Tangents—(Continued)

45°-59.9°

| Degs. | Function | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° |
|-------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 45 | sin | 0.7071 | 0.7083 | 0.7096 | 0.7108 | 0.7120 | 0.7133 | 0.7145 | 0.7157 | 0.7169 | 0.7181 |
| | cos | 0.7071 | 0.7059 | 0.7046 | 0.7034 | 0.7022 | 0.7009 | 0.6997 | 0.6984 | 0.6972 | 0.6959 |
| | tan | 1.0000 | 1.0035 | 1.0070 | 1.0105 | 1.0141 | 1.0176 | 1.0212 | 1.0247 | 1.0283 | 1.0319 |
| 46 | sin | 0.7193 | 0.7206 | 0.7218 | 0.7230 | 0.7242 | 0.7254 | 0.7266 | 0.7278 | 0.7290 | 0.7302 |
| | cos | 0.6947 | 0.6934 | 0.6921 | 0.6909 | 0.6896 | 0.6884 | 0.6871 | 0.6858 | 0.6845 | 0.6833 |
| | tan | 1.0355 | 1.0392 | 1.0428 | 1.0464 | 1.0501 | 1.0538 | 1.0575 | 1.0612 | 1.0649 | 1.0686 |
| 47 | sin | 0.7314 | 0.7325 | 0.7337 | 0.7349 | 0.7361 | 0.7373 | 0.7385 | 0.7396 | 0.7408 | 0.7420 |
| | cos | 0.6820 | 0.6807 | 0.6794 | 0.6782 | 0.6769 | 0.6756 | 0.6743 | 0.6730 | 0.6717 | 0.6704 |
| | tan | 1.0724 | 1.0761 | 1.0799 | 1.0837 | 1.0875 | 1.0913 | 1.0951 | 1.0990 | 1.1028 | 1.1067 |
| 48 | sin | 0.7431 | 0.7443 | 0.7455 | 0.7466 | 0.7478 | 0.7490 | 0.7501 | 0.7513 | 0.7524 | 0.7536 |
| | cos | 0.6691 | 0.6678 | 0.6665 | 0.6652 | 0.6639 | 0.6626 | 0.6613 | 0.6600 | 0.6587 | 0.6574 |
| | tan | 1.1106 | 1.1145 | 1.1184 | 1.1224 | 1.1263 | 1.1303 | 1.1343 | 1.1383 | 1.1423 | 1.1463 |
| 49 | sin | 0.7547 | 0.7559 | 0.7570 | 0.7581 | 0.7593 | 0.7604 | 0.7615 | 0.7627 | 0.7638 | 0.7649 |
| | cos | 0.6561 | 0.6547 | 0.6534 | 0.6521 | 0.6508 | 0.6494 | 0.6481 | 0.6468 | 0.6455 | 0.6441 |
| | tan | 1.4504 | 1.1544 | 1.1585 | 1.1626 | 1.1667 | 1.1708 | 1.1750 | 1.1792 | 1.1833 | 1.1875 |
| 50 | sin | 0.7660 | 0.7672 | 0.7683 | 0.7694 | 0.7705 | 0.7716 | 0.7727 | 0.7738 | 0.7749 | 0.7760 |
| | cos | 0.6428 | 0.6414 | 0.6401 | 0.6388 | 0.6374 | 0.6361 | 0.6347 | 0.6334 | 0.6320 | 0.6307 |
| | tan | 1.1918 | 1.1960 | 1.2002 | 1.2045 | 1.2088 | 1.2131 | 1.2174 | 1.2218 | 1.2261 | 1.2305 |
| 51 | sin | 0.7771 | 0.7782 | 0.7793 | 0.7804 | 0.7815 | 0.7826 | 0.7837 | 0.7848 | 0.7859 | 0.7869 |
| | cos | 0.6293 | 0.6280 | 0.6266 | 0.6252 | 0.6239 | 0.6225 | 0.6211 | 0.6198 | 0.6184 | 0.6170 |
| | tan | 1.2349 | 1.2393 | 1.2437 | 1.2482 | 1.2527 | 1.2572 | 1.2617 | 1.2662 | 1.2708 | 1.2753 |
| 52 | sin | 0.7880 | 0.7891 | 0.7902 | 0.7912 | 0.7923 | 0.7934 | 0.7944 | 0.7955 | 0.7965 | 0.7976 |
| | cos | 0.6157 | 0.6143 | 0.6129 | 0.6115 | 0.6101 | 0.6088 | 0.6074 | 0.6060 | 0.6046 | 0.6032 |
| | tan | 1.2799 | 1.2846 | 1.2892 | 1.2938 | 1.2985 | 1.3032 | 1.3079 | 1.3127 | 1.3175 | 1.3222 |
| 53 | sin | 0.7986 | 0.7997 | 0.8007 | 0.8018 | 0.8028 | 0.8039 | 0.8049 | 0.8059 | 0.8070 | 0.8080 |
| | cos | 0.6018 | 0.6004 | 0.5990 | 0.5976 | 0.5962 | 0.5948 | 0.5934 | 0.5920 | 0.5906 | 0.5892 |
| | tan | 1.3270 | 1.3319 | 1.3367 | 1.3416 | 1.3465 | 1.3514 | 1.3564 | 1.3613 | 1.3663 | 1.3713 |
| 54 | sin | 0.8090 | 0.8100 | 0.8111 | 0.8121 | 0.8131 | 0.8141 | 0.8151 | 0.8161 | 0.8171 | 0.8181 |
| | cos | 0.5878 | 0.5864 | 0.5850 | 0.5835 | 0.5821 | 0.5807 | 0.5793 | 0.5779 | 0.5764 | 0.5750 |
| | tan | 1.3764 | 1.3814 | 1.3865 | 1.3916 | 1.3968 | 1.4019 | 1.4071 | 1.4124 | 1.4176 | 1.4229 |
| 55 | sin | 0.8192 | 0.8202 | 0.8211 | 0.8221 | 0.8231 | 0.8241 | 0.8251 | 0.8261 | 0.8271 | 0.8281 |
| | cos | 0.5736 | 0.5721 | 0.5707 | 0.5693 | 0.5678 | 0.5664 | 0.5650 | 0.5635 | 0.5621 | 0.5606 |
| | tan | 1.4281 | 1.4335 | 1.4388 | 1.4442 | 1.4496 | 1.4550 | 1.4605 | 1.4659 | 1.4715 | 1.4770 |
| 56 | sin | 0.8290 | 0.8300 | 0.8310 | 0.8320 | 0.8329 | 0.8339 | 0.8348 | 0.8358 | 0.8368 | 0.8377 |
| | cos | 0.5592 | 0.5577 | 0.5563 | 0.5548 | 0.5534 | 0.5519 | 0.5505 | 0.5490 | 0.5476 | 0.5461 |
| | tan | 1.4826 | 1.4882 | 1.4938 | 1.4994 | 1.5051 | 1.5108 | 1.5166 | 1.5224 | 1.5282 | 1.5340 |
| 57 | sin | 0.8387 | 0.8396 | 0.8406 | 0.8415 | 0.8425 | 0.8434 | 0.8443 | 0.8453 | 0.8462 | 0.8471 |
| | cos | 0.5446 | 0.5432 | 0.5417 | 0.5402 | 0.5388 | 0.5373 | 0.5358 | 0.5344 | 0.5329 | 0.5314 |
| | tan | 1.5399 | 1.5458 | 1.5517 | 1.5577 | 1.5637 | 1.5697 | 1.5757 | 1.5818 | 1.5880 | 1.5941 |
| 58 | sin | 0.8480 | 0.8490 | 0.8499 | 0.8508 | 0.8517 | 0.8526 | 0.8536 | 0.8545 | 0.8554 | 0.8563 |
| | cos | 0.5299 | 0.5284 | 0.5270 | 0.5255 | 0.5240 | 0.5225 | 0.5210 | 0.5195 | 0.5180 | 0.5165 |
| | tan | 1.6003 | 1.6066 | 1.6128 | 1.6191 | 1.6255 | 1.6319 | 1.6383 | 1.6447 | 1.6512 | 1.6577 |
| 59 | sin | 0.8572 | 0.8581 | 0.8590 | 0.8599 | 0.8607 | 0.8616 | 0.8625 | 0.8634 | 0.8643 | 0.8652 |
| | cos | 0.5150 | 0.5135 | 0.5120 | 0.5105 | 0.5090 | 0.5075 | 0.5060 | 0.5045 | 0.5030 | 0.5015 |
| | tan | 1.6643 | 1.6709 | 1.6775 | 1.6842 | 1.6909 | 1.6977 | 1.7045 | 1.7113 | 1.7182 | 1.7251 |
| Degs. | Function | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' |

Natural Sines, Cosines, and Tangents—(Continued)

60°-74.9°

| Degs. | Function | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° |
|-------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 60 | sin | 0.8660 | 0.8669 | 0.8678 | 0.8686 | 0.8695 | 0.8704 | 0.8712 | 0.8721 | 0.8729 | 0.8738 |
| | cos | 0.5000 | 0.4985 | 0.4970 | 0.4955 | 0.4939 | 0.4924 | 0.4909 | 0.4894 | 0.4879 | 0.4863 |
| | tan | 1.7321 | 1.7391 | 1.7461 | 1.7532 | 1.7603 | 1.7675 | 1.7747 | 1.7820 | 1.7893 | 1.7966 |
| 61 | sin | 0.8746 | 0.8755 | 0.8763 | 0.8771 | 0.8780 | 0.8788 | 0.8796 | 0.8805 | 0.8813 | 0.8821 |
| | cos | 0.4848 | 0.4833 | 0.4818 | 0.4802 | 0.4787 | 0.4772 | 0.4756 | 0.4741 | 0.4726 | 0.4710 |
| | tan | 1.8040 | 1.8115 | 1.8190 | 1.8265 | 1.8341 | 1.8418 | 1.8495 | 1.8572 | 1.8650 | 1.8728 |
| 62 | sin | 0.8829 | 0.8838 | 0.8846 | 0.8854 | 0.8862 | 0.8870 | 0.8878 | 0.8886 | 0.8894 | 0.8902 |
| | cos | 0.4695 | 0.4679 | 0.4664 | 0.4648 | 0.4633 | 0.4617 | 0.4602 | 0.4586 | 0.4571 | 0.4555 |
| | tan | 1.8807 | 1.8887 | 1.8967 | 1.9047 | 1.9128 | 1.9210 | 1.9292 | 1.9375 | 1.9458 | 1.9542 |
| 63 | sin | 0.8910 | 0.8918 | 0.8926 | 0.8934 | 0.8942 | 0.8949 | 0.8957 | 0.8965 | 0.8973 | 0.8980 |
| | cos | 0.4540 | 0.4524 | 0.4509 | 0.4493 | 0.4478 | 0.4462 | 0.4446 | 0.4431 | 0.4415 | 0.4399 |
| | tan | 1.9626 | 1.9711 | 1.9797 | 1.9883 | 1.9970 | 2.0057 | 2.0145 | 2.0233 | 2.0323 | 2.0413 |
| 64 | sin | 0.8988 | 0.8996 | 0.9003 | 0.9011 | 0.9018 | 0.9026 | 0.9033 | 0.9041 | 0.9048 | 0.9056 |
| | cos | 0.4384 | 0.4368 | 0.4352 | 0.4337 | 0.4321 | 0.4305 | 0.4289 | 0.4274 | 0.4258 | 0.4242 |
| | tan | 2.0503 | 2.0594 | 2.0686 | 2.0778 | 2.0872 | 2.0965 | 2.1060 | 2.1155 | 2.1251 | 2.1348 |
| 65 | sin | 0.9063 | 0.9070 | 0.9078 | 0.9085 | 0.9092 | 0.9100 | 0.9107 | 0.9114 | 0.9121 | 0.9128 |
| | cos | 0.4226 | 0.4210 | 0.4195 | 0.4179 | 0.4163 | 0.4147 | 0.4131 | 0.4115 | 0.4099 | 0.4083 |
| | tan | 2.1445 | 2.1543 | 2.1642 | 2.1742 | 2.1842 | 2.1943 | 2.2045 | 2.2148 | 2.2251 | 2.2355 |
| 66 | sin | 0.9135 | 0.9143 | 0.9150 | 0.9157 | 0.9164 | 0.9171 | 0.9178 | 0.9184 | 0.9191 | 0.9198 |
| | cos | 0.4067 | 0.4051 | 0.4035 | 0.4019 | 0.4003 | 0.3987 | 0.3971 | 0.3955 | 0.3939 | 0.3923 |
| | tan | 2.2460 | 2.2566 | 2.2673 | 2.2781 | 2.2889 | 2.2998 | 2.3109 | 2.3220 | 2.3332 | 2.3445 |
| 67 | sin | 0.9205 | 0.9212 | 0.9219 | 0.9225 | 0.9232 | 0.9239 | 0.9245 | 0.9252 | 0.9259 | 0.9265 |
| | cos | 0.3907 | 0.3891 | 0.3875 | 0.3859 | 0.3843 | 0.3827 | 0.3811 | 0.3795 | 0.3778 | 0.3762 |
| | tan | 2.3559 | 2.3673 | 2.3789 | 2.3906 | 2.4023 | 2.4142 | 2.4262 | 2.4383 | 2.4504 | 2.4627 |
| 68 | sin | 0.9272 | 0.9278 | 0.9285 | 0.9291 | 0.9298 | 0.9304 | 0.9311 | 0.9317 | 0.9323 | 0.9330 |
| | cos | 0.3746 | 0.3730 | 0.3714 | 0.3697 | 0.3681 | 0.3665 | 0.3649 | 0.3633 | 0.3616 | 0.3600 |
| | tan | 2.4751 | 2.4876 | 2.5002 | 2.5129 | 2.5257 | 2.5386 | 2.5517 | 2.5649 | 2.5782 | 2.5916 |
| 69 | sin | 0.9336 | 0.9342 | 0.9348 | 0.9354 | 0.9361 | 0.9367 | 0.9373 | 0.9379 | 0.9385 | 0.9391 |
| | cos | 0.3584 | 0.3567 | 0.3551 | 0.3535 | 0.3518 | 0.3502 | 0.3486 | 0.3469 | 0.3453 | 0.3437 |
| | tan | 2.6051 | 2.6187 | 2.6325 | 2.6464 | 2.6605 | 2.6746 | 2.6889 | 2.7034 | 2.7179 | 2.7326 |
| 70 | sin | 0.9397 | 0.9403 | 0.9409 | 0.9415 | 0.9421 | 0.9426 | 0.9432 | 0.9438 | 0.9444 | 0.9449 |
| | cos | 0.3420 | 0.3404 | 0.3387 | 0.3371 | 0.3355 | 0.3338 | 0.3322 | 0.3305 | 0.3289 | 0.3272 |
| | tan | 2.7475 | 2.7625 | 2.7776 | 2.7929 | 2.8083 | 2.8239 | 2.8397 | 2.8556 | 2.8716 | 2.8878 |
| 71 | sin | 0.9455 | 0.9461 | 0.9466 | 0.9472 | 0.9478 | 0.9483 | 0.9489 | 0.9494 | 0.9500 | 0.9505 |
| | cos | 0.3256 | 0.3239 | 0.3223 | 0.3206 | 0.3190 | 0.3173 | 0.3156 | 0.3140 | 0.3123 | 0.3107 |
| | tan | 2.9042 | 2.9208 | 2.9375 | 2.9544 | 2.9714 | 2.9887 | 3.0061 | 3.0237 | 3.0415 | 3.0595 |
| 72 | sin | 0.9511 | 0.9516 | 0.9521 | 0.9527 | 0.9532 | 0.9537 | 0.9542 | 0.9548 | 0.9553 | 0.9558 |
| | cos | 0.3090 | 0.3074 | 0.3057 | 0.3040 | 0.3024 | 0.3007 | 0.2990 | 0.2974 | 0.2957 | 0.2940 |
| | tan | 3.0777 | 3.0961 | 3.1146 | 3.1334 | 3.1524 | 3.1716 | 3.1910 | 3.2106 | 3.2305 | 3.2506 |
| 73 | sin | 0.9563 | 0.9568 | 0.9573 | 0.9578 | 0.9583 | 0.9588 | 0.9593 | 0.9598 | 0.9603 | 0.9608 |
| | cos | 0.2924 | 0.2907 | 0.2890 | 0.2874 | 0.2857 | 0.2840 | 0.2823 | 0.2807 | 0.2790 | 0.2773 |
| | tan | 3.2709 | 3.2914 | 3.3122 | 3.3332 | 3.3544 | 3.3759 | 3.3977 | 3.4197 | 3.4420 | 3.4646 |
| 74 | sin | 0.9613 | 0.9617 | 0.9622 | 0.9627 | 0.9632 | 0.9636 | 0.9641 | 0.9646 | 0.9650 | 0.9655 |
| | cos | 0.2756 | 0.2740 | 0.2723 | 0.2706 | 0.2689 | 0.2672 | 0.2656 | 0.2639 | 0.2622 | 0.2605 |
| | tan | 3.4874 | 3.5105 | 3.5339 | 3.5576 | 3.5816 | 3.6059 | 3.6305 | 3.6554 | 3.6806 | 3.7062 |
| Degs. | Function | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' |

Natural Sines, Cosines, and Tangents—(Continued)

75°-89.9°

| Degs. | Function | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° |
|-------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 75 | sin | 0.9659 | 0.9664 | 0.9668 | 0.9673 | 0.9677 | 0.9681 | 0.9686 | 0.9690 | 0.9694 | 0.9699 |
| | cos | 0.2588 | 0.2571 | 0.2554 | 0.2538 | 0.2521 | 0.2504 | 0.2487 | 0.2470 | 0.2453 | 0.2436 |
| | tan | 3.7321 | 3.7583 | 3.7848 | 3.8118 | 3.8391 | 3.8667 | 3.8947 | 3.9232 | 3.9520 | 3.9812 |
| 76 | sin | 0.9703 | 0.9707 | 0.9711 | 0.9715 | 0.9720 | 0.9724 | 0.9728 | 0.9732 | 0.9736 | 0.9740 |
| | cos | 0.2419 | 0.2402 | 0.2385 | 0.2368 | 0.2351 | 0.2334 | 0.2317 | 0.2300 | 0.2284 | 0.2267 |
| | tan | 4.0108 | 4.0408 | 4.0713 | 4.1022 | 4.1335 | 4.1653 | 4.1976 | 4.2303 | 4.2635 | 4.2972 |
| 77 | sin | 0.9744 | 0.9748 | 0.9751 | 0.9755 | 0.9759 | 0.9763 | 0.9767 | 0.9770 | 0.9774 | 0.9778 |
| | cos | 0.2250 | 0.2232 | 0.2215 | 0.2198 | 0.2181 | 0.2164 | 0.2147 | 0.2130 | 0.2113 | 0.2096 |
| | tan | 4.3315 | 4.3662 | 4.4015 | 4.4374 | 4.4737 | 4.5107 | 4.5483 | 4.5864 | 4.6252 | 4.6646 |
| 78 | sin | 0.9781 | 0.9785 | 0.9789 | 0.9792 | 0.9796 | 0.9799 | 0.9803 | 0.9806 | 0.9810 | 0.9813 |
| | cos | 0.2079 | 0.2062 | 0.2045 | 0.2028 | 0.2011 | 0.1994 | 0.1977 | 0.1959 | 0.1942 | 0.1925 |
| | tan | 4.7046 | 4.7453 | 4.7867 | 4.8288 | 4.8716 | 4.9152 | 4.9594 | 5.0045 | 5.0504 | 5.0970 |
| 79 | sin | 0.9816 | 0.9820 | 0.9823 | 0.9826 | 0.9829 | 0.9833 | 0.9836 | 0.9839 | 0.9842 | 0.9845 |
| | cos | 0.1908 | 0.1891 | 0.1874 | 0.1857 | 0.1840 | 0.1822 | 0.1805 | 0.1788 | 0.1771 | 0.1754 |
| | tan | 5.1446 | 5.1929 | 5.2422 | 5.2924 | 5.3435 | 5.3955 | 5.4486 | 5.5026 | 5.5578 | 5.6140 |
| 80 | sin | 0.9848 | 0.9851 | 0.9854 | 0.9857 | 0.9860 | 0.9863 | 0.9866 | 0.9869 | 0.9871 | 0.9874 |
| | cos | 0.1736 | 0.1719 | 0.1702 | 0.1685 | 0.1668 | 0.1650 | 0.1633 | 0.1616 | 0.1599 | 0.1582 |
| | tan | 5.6713 | 5.7297 | 5.7894 | 5.8502 | 5.9124 | 5.9758 | 6.0405 | 6.1066 | 6.1742 | 6.2432 |
| 81 | sin | 0.9877 | 0.9880 | 0.9882 | 0.9885 | 0.9888 | 0.9890 | 0.9893 | 0.9895 | 0.9898 | 0.9900 |
| | cos | 0.1564 | 0.1547 | 0.1530 | 0.1513 | 0.1495 | 0.1478 | 0.1461 | 0.1444 | 0.1426 | 0.1409 |
| | tan | 6.3138 | 6.3859 | 6.4596 | 6.5350 | 6.6122 | 6.6912 | 6.7720 | 6.8548 | 6.9395 | 7.0264 |
| 82 | sin | 0.9903 | 0.9905 | 0.9907 | 0.9910 | 0.9912 | 0.9914 | 0.9917 | 0.9919 | 0.9921 | 0.9923 |
| | cos | 0.1392 | 0.1374 | 0.1357 | 0.1340 | 0.1323 | 0.1305 | 0.1288 | 0.1271 | 0.1253 | 0.1236 |
| | tan | 7.1154 | 7.2066 | 7.3002 | 7.3962 | 7.4947 | 7.5958 | 7.6996 | 7.8062 | 7.9158 | 8.0285 |
| 83 | sin | 0.9925 | 0.9928 | 0.9930 | 0.9932 | 0.9934 | 0.9936 | 0.9938 | 0.9940 | 0.9942 | 0.9943 |
| | cos | 0.1219 | 0.1201 | 0.1184 | 0.1167 | 0.1149 | 0.1132 | 0.1115 | 0.1097 | 0.1080 | 0.1063 |
| | tan | 8.1443 | 8.2636 | 8.3863 | 8.5126 | 8.6427 | 8.7769 | 8.9152 | 9.0579 | 9.2052 | 9.3572 |
| 84 | sin | 0.9945 | 0.9947 | 0.9949 | 0.9951 | 0.9952 | 0.9954 | 0.9956 | 0.9957 | 0.9959 | 0.9960 |
| | cos | 0.1045 | 0.1028 | 0.1011 | 0.0993 | 0.0976 | 0.0958 | 0.0941 | 0.0924 | 0.0906 | 0.0889 |
| | tan | 9.5144 | 9.6768 | 9.8448 | 10.02 | 10.20 | 10.39 | 10.58 | 10.78 | 10.99 | 11.20 |
| 85 | sin | 0.9962 | 0.9963 | 0.9965 | 0.9966 | 0.9968 | 0.9969 | 0.9971 | 0.9972 | 0.9973 | 0.9974 |
| | cos | 0.0872 | 0.0854 | 0.0837 | 0.0819 | 0.0802 | 0.0785 | 0.0767 | 0.0750 | 0.0732 | 0.0715 |
| | tan | 11.43 | 11.66 | 11.91 | 12.16 | 12.43 | 12.71 | 13.00 | 13.30 | 13.62 | 13.95 |
| 86 | sin | 0.9976 | 0.9977 | 0.9978 | 0.9979 | 0.9980 | 0.9981 | 0.9982 | 0.9983 | 0.9984 | 0.9985 |
| | cos | 0.0698 | 0.0680 | 0.0663 | 0.0645 | 0.0628 | 0.0610 | 0.0593 | 0.0576 | 0.0558 | 0.0541 |
| | tan | 14.30 | 14.67 | 15.06 | 15.46 | 15.89 | 16.35 | 16.83 | 17.34 | 17.89 | 18.46 |
| 87 | sin | 0.9986 | 0.9987 | 0.9988 | 0.9989 | 0.9990 | 0.9990 | 0.9991 | 0.9992 | 0.9993 | 0.9993 |
| | cos | 0.0523 | 0.0506 | 0.0488 | 0.0471 | 0.0454 | 0.0436 | 0.0419 | 0.0401 | 0.0384 | 0.0366 |
| | tan | 19.08 | 19.74 | 20.45 | 21.20 | 22.02 | 22.90 | 23.86 | 24.90 | 26.03 | 27.27 |
| 88 | sin | 0.9994 | 0.9995 | 0.9995 | 0.9996 | 0.9996 | 0.9997 | 0.9997 | 0.9997 | 0.9998 | 0.9998 |
| | cos | 0.0349 | 0.0332 | 0.0314 | 0.0297 | 0.0279 | 0.0262 | 0.0244 | 0.0227 | 0.0209 | 0.0192 |
| | tan | 28.64 | 30.14 | 31.82 | 33.69 | 35.80 | 38.19 | 40.92 | 44.07 | 47.74 | 52.08 |
| 89 | sin | 0.9998 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| | cos | 0.0175 | 0.0157 | 0.0140 | 0.0122 | 0.0105 | 0.0087 | 0.0070 | 0.0052 | 0.0035 | 0.0017 |
| | tan | 57.29 | 63.66 | 71.62 | 81.85 | 95.49 | 114.6 | 143.2 | 191.0 | 286.5 | 573.0 |
| Degs. | Function | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' |

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FOREWORD

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Allied Radio Corporation has long recognized the need for a comprehensive and condensed handbook of formulas and data most commonly used in the field of radio and electronics. It was felt also that such a book should serve entirely as a convenient source of information and reference and that all attempts to teach or explain the basic principles involved should be left to classroom instruction and to the many already existing publications written for this distinct purpose.

The *Electronics Data Handbook*, therefore, consists of formulas, tables, charts and data. Every effort has been made to present this information clearly and to arrange it in a convenient manner for instant reference. All material was carefully selected and prepared by *Allied's* technical staff to serve the requirements of many specific groups in the radio and electronics field. It is hoped that our objectives have been successfully attained and that this *Handbook* will serve as: (1) A valuable adjunct to classroom study and laboratory work for the student and instructor; (2) A dependable source of information for the beginner, experimenter and set builder; (3) A reliable guide for the service engineer and maintenance man in his everyday work; (4) A time-saving and practical reference for the radio amateur, technician and engineer, both in the laboratory and in the field of operations.

The publishers are indebted to the McGraw-Hill Book Company, Inc., for their permission to use material selected from "*Mathematics for Electricians and Radiomen*" by Nelson M. Cooke. *Allied* also takes this opportunity to thank those manufacturers who so generously permitted our use of current data prepared by their engineering personnel. Special recognition and our sincere appreciation are extended to Commander Cooke for his helpful suggestions and generous contribution of his time and specialized knowledge in editing the material contained in this book.

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